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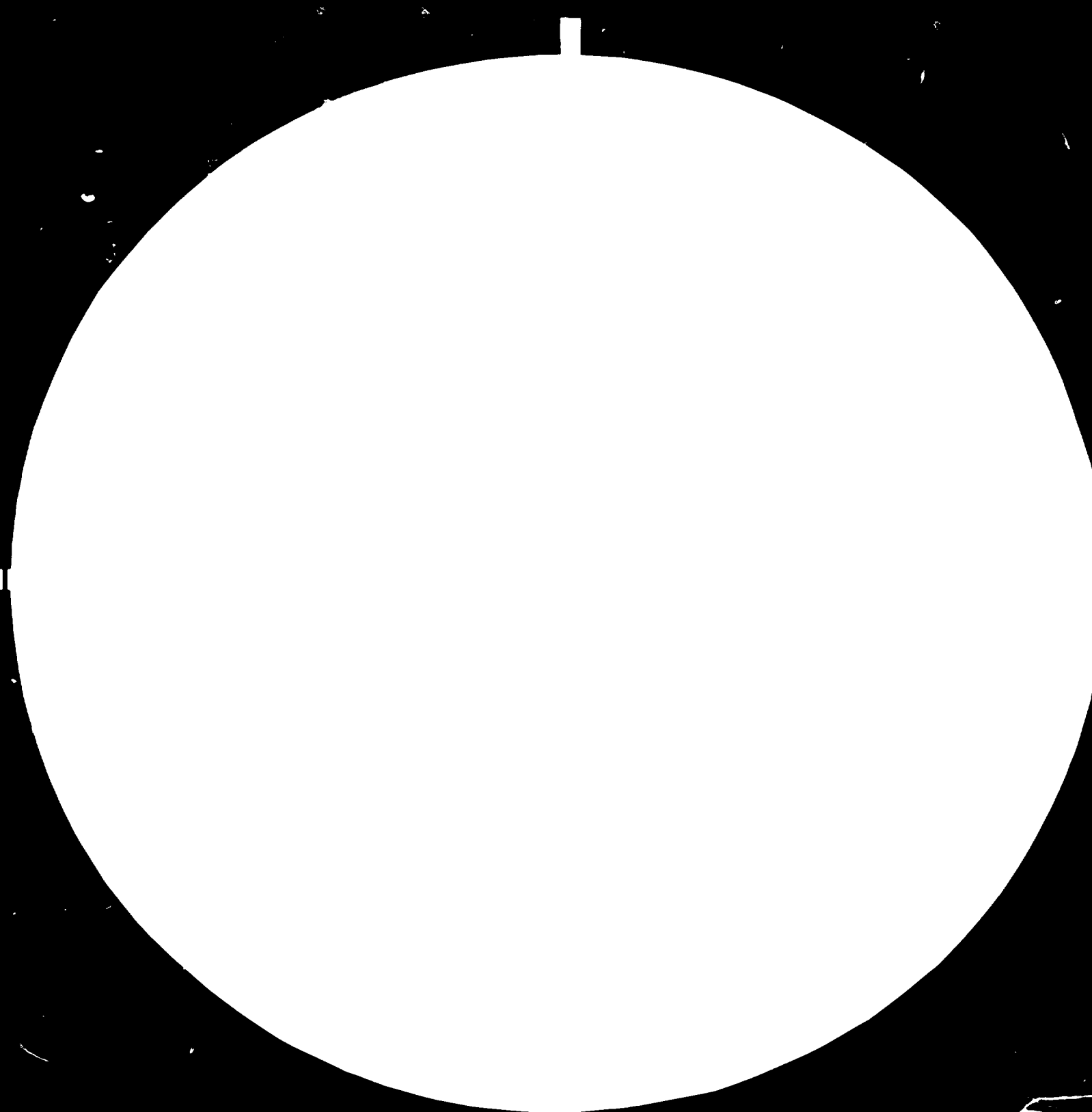

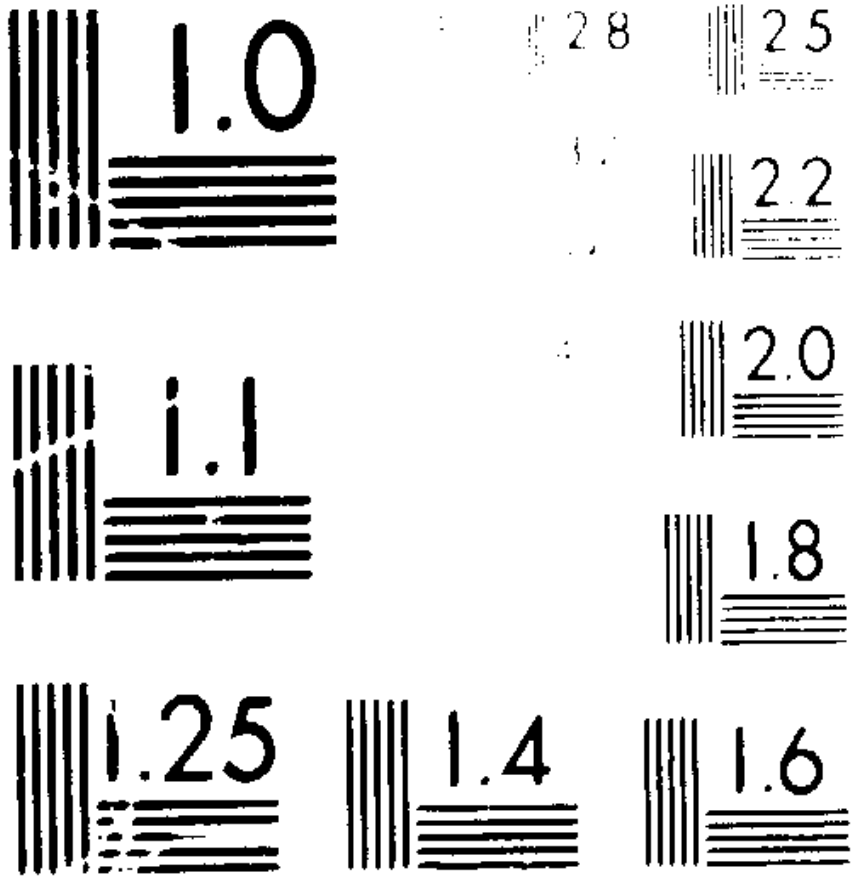
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20 February 1980
ENGLISH

ASSISTANCE IN THE ESTABLISHMENT OF CLAY PRODUCTS MANUFACTURE

SI/TTP/79/801

TRUST TERRITORY OF THE PACIFIC ISLANDS

Technical report: Field survey of some clay deposits in Yap, Palau and Truk*

Prepared for the Trust Territory of the Pacific Islands by
the United Nations Industrial Development Organization,
executing agency for the United Nations
Development Programme

Based on the work of Neville R. Hill, field geologist

United Nations Industrial Development Organization
Vienna

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CONTENTS

.....continued/

1. INTRODUCTION

1.1. Purpose of the Mission

This assignment called for a field geologist to carry out Phase I of the UNIDO Project SI/TTP/79/801 for the Government of the Trust Territory of the Pacific Islands (TTPI) "Assistence in the Establishment of Clay Products Manufacture". (See the Project Proposal by UNIDO dated 17th July 1979).

The specific duties of the field geologist, listed in the Job Description SI/TTP/79/801/11-01/32.1.B, were:-

1. Study available information on clay deposits (and related test results) in the Palau,Yap and Truk Districts;
2. Carry out a geological survey of clay deposits in the three districts with the logistic support of the Public Works Department and other District Headquarters facilities;
3. Ascertain the quantity, depth and consistency of the clay deposits and their accessibility to the Centre;
4. Collect representative samples from the surveyed deposits for the laboratory testing;
5. Prepare a report on his findings and recommendations.

During briefing in Vienna, in Suva (UNDP) and in the Bureau of Resources at TTPI headquarters in Saipan, the field geologist did not find cause to change these duties as the priorities of the mission. With the substantive officer in UNIDO, it was agreed that, time permitting, the expert would consider what other building materials, besides clay products, might be appropriate to manufacture locally. Discussions in Saipan as well as with district administrators, indicated a strong preference for establishing small-scale, low capital cost and easily handled production units, using technology of an intermediate level.

1.2. Previous Related Work by UNIDO

There had been no previous work by a UNIDO expert in the TTPI, according to UNIDO in Vienna. However, the Senior Industrial Development Field Adviser (SIDFA) for UNIDO

in the South Pacific Region, which includes TTPI, Mr. Sergio Dello-Strologo,who is based at the UNDP office in Suva, Fiji, has been active in promoting this project and has personally arranged for the previous collection of clay samples and their testing in the U.S.A.

There is a UNDP team, headed by a Senior Economic Adviser based in Saipan, which is working on development planning for the Federated States of Micronesia (FSM). Included in their programme has been an appraisal of the proposed project for a laterite block plant in Ponape.

1.3. Intended Follow Up Work

Depending on the findings of this first phase, the Project Proposal provides for two further stages:-

Phase II: will entail the testing of the samples,collected during Phase I, at a competetent laboratory abroad and a report, based on the results, on the industrial applicability of the clays.

Phase III: a ceramic technologist would assess the local market for structural clay products, pottery, ceramic filters, etc., prepare feasibility studies for production units appropriate in size and level of technology and include estimates of investment and operating costs, etc.

The main development objective of the project is to promote indigenous industrial activity based on local raw materials.

2.SUMMARY OF AVAILABLE INFORMATION

Considerable information is available about the clay horizons that occur in the islands of Micronesia through the series of Military Geology reports prepared 25 years ago by Intelligence Division, Office of the Engineer, Headquarters U.S.Army Forces, Far East, copies of which exist for Yap, Palau and Truk, as well as certain other islands, in the Division of Lands of the Bureau of Resources at the Department of Development Services, TTPI Government in Saipan. (Tnese are no longer classified material). Many maps show the distribution of soils and construction materials, etc., and there is in some an account of previous economic mineral

development activity, including the utilization of clays.

Other relevent data about the clay deposits exists in the reports by Herbert Meyer, of December 1977, on the "Ngersuul Pottery at Kless, Babeldaob, Palau" and by Sandy Vitarelli, of August 1977, entitled "Ceramic Research & Teaching Program of Palau High School". The clay deposits on Palau, as well as on Ponape, were sampled in about 1976, at the request of Mr. Dello-Strologo, and sketch maps showing the approximate locality of the sample points are available. Finally, there are the results of the laboratory testing of those clay samples, reported to Mr. Dello-Strologo, by New York State College of Ceramics at New York State University in Alfred, NY., in 1979.

Information on the previous history of ceramic activity on Yap, Palau and Truk has been obtained from local people and the "Military Geology" of Palau, at pp.267 to 268, has details of the production of structural clay products there in 1939-42.

2.1. Yap

From Map 1, Geology, of the Military Geology report, the legend suggests that only the clays forming the weathered surface of the Tomil Volcanics (Miocene) formation, extending to maximum depths of more than 60 ft, make up clay deposits of any appreciable thickness and occur not only in Gagil-Tomil but also in the area of the airfield and southwards. However, examination of Map 2, Soils, in conjunction with test results on Table 17 and Map 4, Construction Materials, taken with Table 19 Engineering Test Data, indicate that besides the above mentioned clay, there is a second with characteristics potentially suitable for ceramic purposes. This is Unit 11, on Map 4, which occurs principally in Dalipebinau, from Derikan in the west to near Gitam. Other soil units can be ruled out of consideration for reasons of the presence of too much gravel, organic matter and close proximity of the water table, etc. The important features of the two interesting clays are as follows:-

Unit 7: 'Red clayey silt'. Weathered surface of the Tomil Volcanics. Occurs mainly near and to the south west of the airport and in Gagil-Tomil. Little or no gravel,

sand(0.074-4.76mm) averages 28%, fines (below 0.074mm) averages 70%. Plastic Limit av. 40%, Plasticity Index av. 25%. Shrinkage low. Water table depth 30 ft.

Unit 11: 'Clayey sand over fat clay'. Weathered surface of the Yap green schists. Occurs in Dalipebina , especially between Gitam and Derikan. Usually no gravel size material, sand av.39%, fines av. 61%, PL av. 40%, PI av. 29%. Shrinkage negligible in the surface foot but very high beneath. Water table at 3 to 4 feet in wet season.

Note: Unit 12:'Silty sand and silt over fat clay', would be a possibility except for its content of up to 29% of gravel (4.76 to 16.2mm).

As regards previous ceramic activities on Yap, it is known that in at least one location women used to make pots by coiling the clay. Those people are no longer alive. In Yap it was learned that pots were made in Gitam, Ngof and Gachlau - Gitam, incidentally, is close to the "Unit 11" clay and the other two villages are by the "Unit 7" clay. There is now no making of pottery or other ceramic items on Yap proper except for the small concrete block factory just south of the bridge in Colonia.

2.2. Palau

From the map forming Plate 27,Engineering Geology, of the 'Military Geology for Palau', there appear to be three potential sources of clay, geologically, which are:

the weathered volcanic tuff and breccia,
the sedimentary clay with lignite,
the alluvium.

By considering the Engineering Soils Map, Plate 30, in conjunction with sheets 1 and 2 of Table 16, giving description and engineering test data, the information of ceramic significance about these three sources of clay can be summarized thus:

Sedimentary clay with lignite. In the Districts of Airai (e.g. around the airport and at Oikul), Aimelik (on the south side of Karamado Bay) and Ngatpang (east side of Karamado Bay and on the island of Ngerasch). Division has been made by the

soils engineers into two sub-groups:

Unit 1. Red soils over grey clays . Subsoil is red or reddish-yellow plastic clay. Substratum can be from 30 to 100 feet of variegated red and yellow, moderately plastic clay becoming grey with depth. Where not eroded is covered with ferns, grasses and shrubs. Sand av.11%, fines av.87%. PL av.50%, PI av.23%.

Unit 2. Yellow soils over grey clays. Subsoil is pale yellow to light yellowish brown, sticky and plastic. The substratum can be 30 to 100 feet of light grey clay, very plastic and may include the black lignite (a type of low grade coal). Where not eroded has grass and trees, e.g. pandanus. Sand av.13%, fines av. 86%. PL av. 44%, PI av. 32%.

The above data suggests these could be important and readily accessible sources of ceramic raw material. Vitarelli has described these clays from Airai (south of the airport) as being grey, very plastic, tight though containing 'lime'.(But chemical analyses at Alfred, NY do not support the existence of a significant amount of CaO).The NY State University tests found the Airai clays (three samples) to have good characteristics for throwing on a potter's wheel, or even too plastic on their own, like a ball clay. The drying shrinkage, 9 to 13%, is higher than desired but there was little problem with firing, usually to a white, pale yellow or pale blue-grey. A sample from Ngatpang had similar ceramic properties except for firing to a pale red or greyish-red. On the other hand, two samples tested from Ngerasch island were said to be not good for throwing, i.e. for pottery, but might be for structural clay products. They fired white or red with a fairly high porosity.(In fact bricks, tiles, etc. were made at Ngerasch in 1939 to 1942).

A summary of the results of the NY State University, testing is given in Appendix IV.

Weathered volcanic tuff and breccia. The soils engineers have sub-divided this into three Units, 3, 4 and 5, on the Engineering Soils Map, Pl.30, and these, pink and pale red on the map, are seen to cover possibly 90% of Babelthuap. Hence

they occur adjacent to the previously considered sedimentary clay with lignite and so constitute further potential ceramic raw material for the three Districts of Airai, Aimelik and Ngatpang. In general, beneath the predominantly reddish surface soil, there is a substratum of 10 to 50 feet or more of red, yellow to brown, only slightly plastic, friable, and rather sandy clays. Alone, these lateritic, or even bauxitic, materials are not likely to be useable for making fired clay products, due their low plasticity for moulding purposes and possibly needing an unacceptably high firing temperature, owing to the lack of fluxing components which have been leached out by weathering. (The so called 'laterite blocks' are not hardened by firing but by moulding under very high pressure and a subsequent chemical reaction between the alumina component of the laterite and 5 to 7% of lime, $Ca(OH)_2$, mixed with it). The relevant characteristics of the soils, summarized from the data on sheets 1 and 2 of Table 16 of the Military Geology, are as follows:

Unit No.	Name	Mech.Analysis		Atterberg Values*	
		Sand	Fines	PL	PI
3	Friable, red lateritic soils from volc.rocks.	28	70	45	15
4	Friable red bauxitic soils from volc.rocks.	25	66	42	13
5	Friable lateritic red soils from tuffs	10	88	58	18

* PL= Plastic Limit, PI= Plasticity Index.

It may be that the sample no.C-1 from Ngerdmau tested by the NY State University ceramic laboratory was one of these lateritic or bauxitic soils as Ngerdmau was the centre for the mining of bauxite in the past. Not surprisingly, if that was the case, it was found not good for throwing pots, it fired to a dark red-grey (presumably due to its high iron content) and was suggested as being of use for bricks, or coloured slips and engobes.

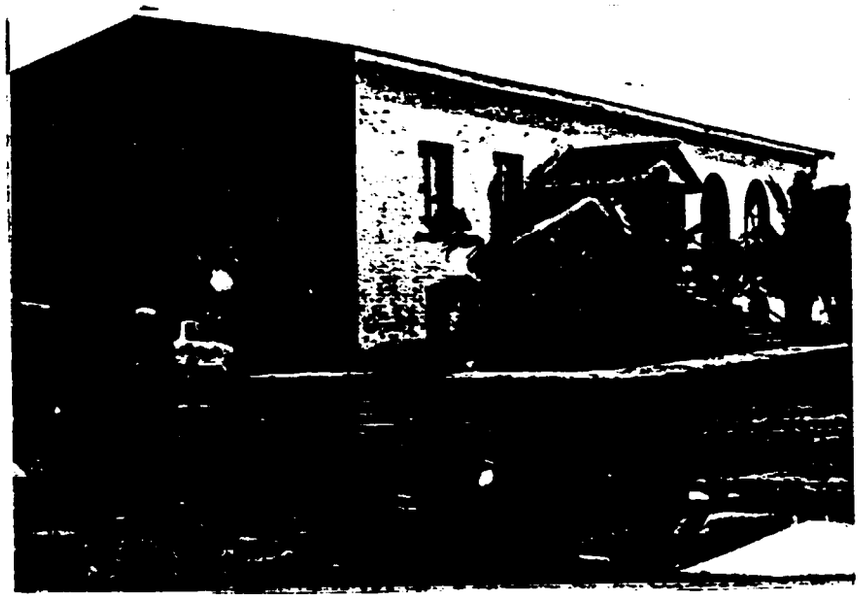
These materials have potential ceramic use if it is required to reduce the rather high plasticity, as well as drying shrinkage, of the important sedimentary or 'Airai' clays, by blending various amounts with them as necessary.

Alluvium. This occurs in the flood plains of various rivers, including many of those in the Districts of Airai, Aimelik and Ngatpang. On the Engineering Soils Map of Pl.30 and the Engineering Test Data of Table 16 the alluvium, which is of Recent age, is divided into two groups depending on how well drained it is. Its significant characteristics as a ceramic raw material can be summarized as follows:

Unit No.	Name	Mech. Analysis		Atterberg Values	
		Sand	Fines	PL	PI
7	Deep, well drained soils on flood plains	20	80	46	18
8	Deep, poorly drained soils on flood plains	10	90	51	17

The water table is within 1 foot of the surface in Unit 8 and to 4 feet in Unit 7 in the wet season and hence extraction of the material by digging could be difficult. As the granulometry and plasticity are not much different from the lateritic soils this may not matter but these alluvial clays should not be ignored as possible body builders, i.e. to adjust the moulding, drying and firing performance of the main raw materials.

Of the three States or Districts of Yap, Palau and Truk, Palau had by far the most ceramic activity, which is not surprising in view of the variety and accessibility of its raw materials. There have been at least three periods when this took place. The Palauans themselves are said to have produced pottery long ago at Ngerard and Ngatpang. Then, in 193?-42, about ½ million bricks, tiles, pipes, etc. were made by an Okinawan on Ngerasch island. Since about 1970 and until six months ago, pottery was made, mainly,it seems,as a cultural enterprise by foreign potters, at the Ngarsuul Pottery in the village of Kless and during two episodes at the Palau High School on Koror.(More details are given in Appendix VI which also includes details of the sample locations visited during the present mission, in Palau.) Much information about the deposits of white clay at Oikul (= Goikul in Japanese) and the clay with lignite at Ngerasch, as well as



PALAU

STRUCTURAL CLAY PRODUCTS MADE IN NGERASCH c.1940.

The Legislature Building in Koror.

A corner of the Legislature Building in Koror. Showing the fired clay brick ork beneath a surface decorative coating.

Examples of pressed roof tiles lying at the site of the 1937-42 factory on Ngeraoch Island.

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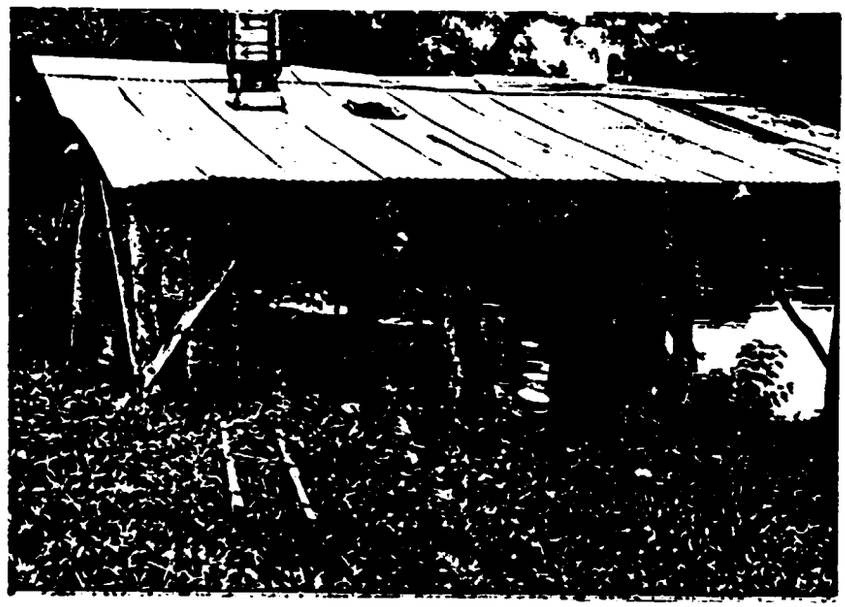
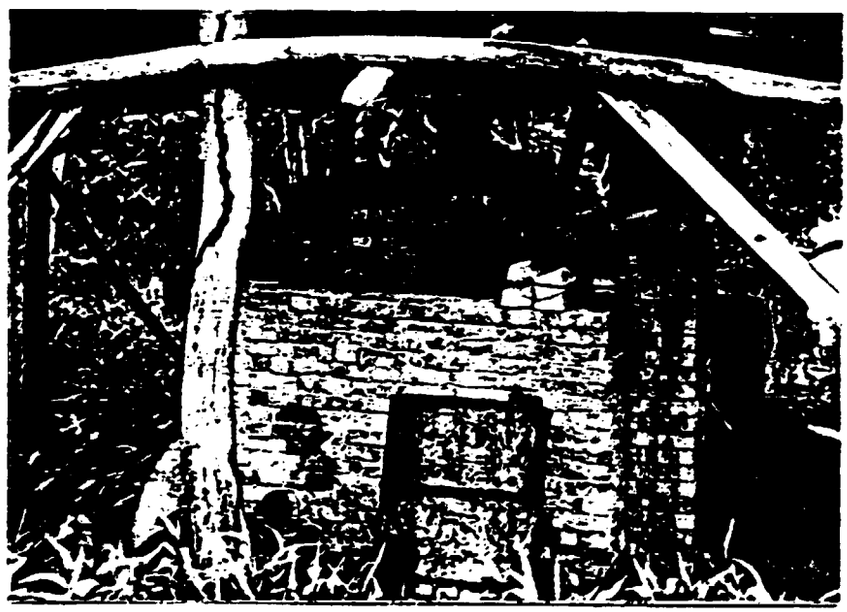


PALAU

THE KILN HOUSE FOR THE NGARSUUL POTTERY AT KLOSS



According to the inventory of equipme made by Herbert Mayh one of the kilns is 75 ft^3 down draught catenary arch kiln and the other is a 30 ft^3 down draught sprung arch kiln. They are fired using a Japanese diesel oil burner.

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the calorific and other analyses of the lignite and the 1939-1942 ceramic production on Ngerasch, are given in the Military Geology of Palau and are summarized in this report in Appendix VI. Appendix VI also lists the existing equipment in the two potteries.

2.3. Truk. According to the report "Military Geology of Truk Islands, Caroline Islands", of which the relevant work on soils was done 25 years ago by J.E.Paseur, there are two main clay formations in the Truk Islands; the Truk Clay and the Truk Stony Clay. They are described in detail from p.91 onwards in the report and shown for the islands of Moen and Dublon on Maps 13 and 14 of that report. The test data of use in this present mission is the Soils Mechanics Test Data of Table 20, p.155. (A third clayey horizon, the Fefan Soils, consists of thin limonitic gravelly clays which can be excluded as potential ceramic raw material).

Truk Clay. Covers 23% of the volcanic uplands and is a residual clay developed on volcanic bedrock, etc., and the upper 10 feet are usually free from boulders. It is reddish-brown and slightly plastic. On slopes of less than 25%, it can extend down to 10 to 50 feet depth. The granulometry and plasticity data of the three samples taken by J.E.Paseur are as follows:

Sand	Fines	Atterberg Values	
0.074-2mm	below 0.074mm	PL	PI
25	75	49	12
14	86	53	26
8	92	58	14

Truk Stony Clay. Is the most common soil , at least on Moen and Dublon, covering more than 50% of the surface. It is mostly reddish-brown to yellowish-brown clay, slightly plastic to plastic and with 15 to 20% or more of stones and boulders present. The thickness is variable, from as little as 1 foot to as much as 30 feet. The single sample taken by Paseur showed:

Sand	Fines	Atterberg Values	
		PL	PI
14	86	41	11

Although both these clays are widespread in their occurrence and readily accessible, the above data indicates that neither has the desirable 'range of plasticity', shown by a higher Plasticity Index (PI), which would make them suitable for pottery

or relatively thin-walled products such as hollow bricks and blocks and probably the only potential use is for the hand making, either by slop moulding or preferably by sand moulding, of solid fired clay bricks.

This may explain why the field geologist for this present mission could find no mention of any previous ceramic activity by the Truk people, though it had been suggested that the Japanese may have done something in the ceramic line. (The book 'The Material Culture of Truk', by Frank M.LeBar, 1964,published by the Dept. of Anthropology of Yale University, deals comprehensively with the cooking ware, building materials, etc., etc., that were used and there are no ceramic items mentioned, except for a cement for caulking made from lime and coconut spathe ashes. Breadfruit and taro were boiled in, for example,a shell vessel made by removing the inner part of a trochus or conch shell. Similarly 'Preliminary Archaeological Investigations on the Island of Toll, in Truk', by Jan Takayama and Toshi Ikoseki, describes many artifact found there but no pottery. The Economy of the Truk Islands, an Anthropological and Economic Survey'by Edward T.Hall and Carl J.Pelser, published by the U.S.Commercial Co.,Honolulu in 1946, also mentions no pottery production . Under 'Trade and Industry' it describes wooden bowls as being the receptacles used. All of this strongly suggests that such an ancient and basic art as pottery making was not possible in the Truk Islands otherwise the migrants from Indonesia and the Philippines, including some from Palau, would have introduced it).

3. FIELD WORK

A total time of 7½ days was spent on geological field work, either by vehicle or on foot, distributed thus: Yap 3 (all on Yap Islands proper), Palau 2½ (all on Babelthuap) and Truk 2 (all on Moen - a day planned for Dublon had to be abandoned owing to lack of transport to that island).(As a percentage of the total mission time of six weeks this is very low, only 18%, and indicates the high proportion of time that had to be spent on travelling to and from the Duty Station, via Vienna and Fiji, and on travel between the islands via Guam).

At each of the three district centres, the field geologist received the logistic support of the appropriate government personnel, whose names are listed in Appendix III. In Yap the counterpart department was the Resources & Development Department, in Palau the offices of Economic Development and of Land Management and in Truk the office of Land Management. In addition, brief meetings were held with Governors or District Administrators.

The method of investigation consisted of reconnaissance survey, by vehicle and on foot, using the soils or engineering geology maps of the 'Military Geology' reports, on a scale of 1:25,000 or 1:62,500. The odometer readings of the vehicle were noted as an aid to determining location and the precise position of exposures of clay beds and sample points was noted by recording the magnetic compass bearing to prominent fixed points, such as radio masts, and the distance in metres, to an accuracy of ± 5%, by means of a hand held rangefinder in the range 46 to 1000m. The taking of soil samples, of not less than 10kg in weight, was by means of shallow hand auger holes and pits. The detailed data on the location of the exposures and sample points and the thickness and visual characteristics of the clays there, are given in the three initial reports,made at the time of the visits to the three states/districts, and included here as Appendices V, VI and VII.

3.1. <u>Conclusions on the Extent, Depth, Likely Thickness and Character of the Clay Deposits, and their Accessibility</u>.

Without a full, and expensive, borehole programme, the determination of 'proven' reserves of the clays in any locality has not been possible. By observation in the field and the interpretation of the appropriate data in the Military Geology reports, it has been possible to ascertain that adequate quantities of certain clays exist, though not necessarily in each case of the quality needed for pottery or structural clay products manufacture. Similarly, of the four operations that a clay has to undergo, as a ceramic raw material,i.e. preparation, moulding, drying and firing, field investigation can provide fairly certain

data on the ease of preparation. Examination and feel of the material, including clay which has been dried by the sun, may indicate the probable moulding and drying behaviour. Without actually firing the material in a kiln, no conclusion on probable firing behaviour is possible.

3.1.1. Yap. Three clays, of different origin, together likely to be suitable raw materials for establishing small scale ceramic manufacture, at least simple pots and solid hand moulded bricks, have been located on the Yap islands proper. Yellow-brown Clay - weathered surface of the Yap Green Schists, (forms Unit 11 'Clayey sand over fat clay' of Map 4 of the Military Geology report). Seen and sampled just north-east * of the airport crossroads, at Derikan.Present there at the depth interval 20-75cm, i.e. 55cm thick, bro nish-yellow colour, uniform, plastic, 20cm overburden of stony soil and underlain by hard green schist. Easily accessible. Rather too thin for supplying medium scale mechanized production units owing to the large area of land that would have to be purchased or leased. Occurs in Dalipebinau, from Derikan in the west to Gitam in the east, a distance of at least 2km. Is almost certainly the raw material used by the women who at one time coiled the clay to make pots in Gitam.(A resident of Gitam, Mr. Al Figirmow, mentioned that, in the view of the Professor of Art in the Guam University, the best clay for pottery in Yap exists in Dinay and Gitam). Sample No. 261179C (Similar material was seen and sampled near Numnung, where 60cm of brown-yellow plastic clay was exposed in a bank beneath 20cm of stony soil. There the material is that shown as unit 12 on Map 4, and which is of vast extent over Weloy and Fanif. Sample No. 271179A)

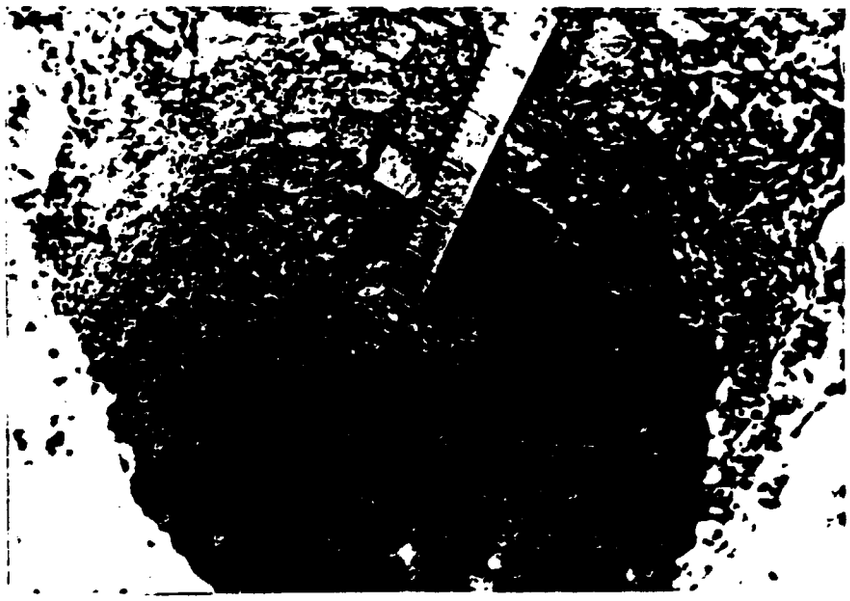
Reddish-brown mottled Clay - weathered surface of the Tomil Volcanics Formation. (forms Unit 7 'Red clayey silt' of Map 4 of the Military Geology Report). Seen and sampled to the south-west of the airport crossroads, near Derikan, and to the north-east of the nearby lake. A hole dug in an area there free from vegetation, found mottled brown and light red stiff clay, uniform and free from stones, from the surface to

* a new airfield runway is to be built near there.

YELLOW-BROWN CLAY ON YAP

Location of Sample 261179C
near Derikan (airport)

55cm of clay beneath surface
stones and above green schist.
Sample Hole 261179C.



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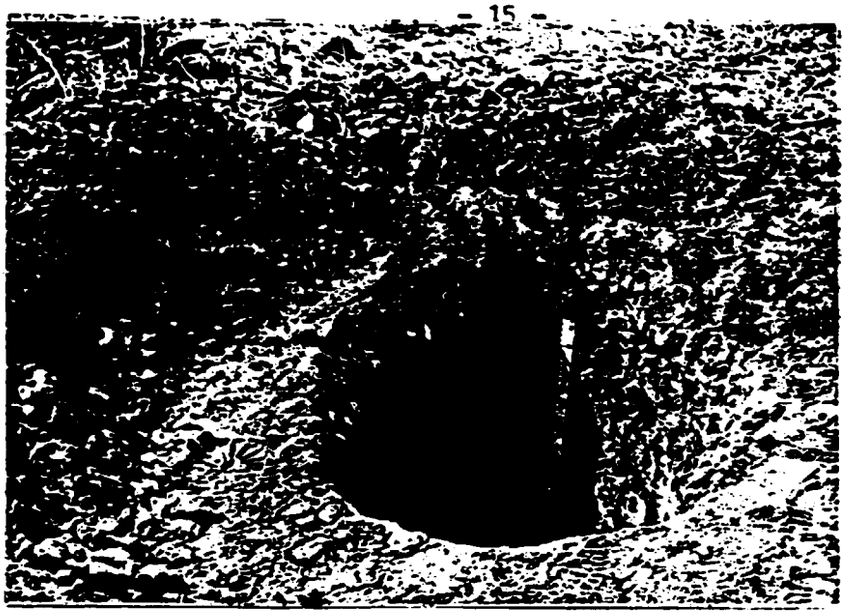

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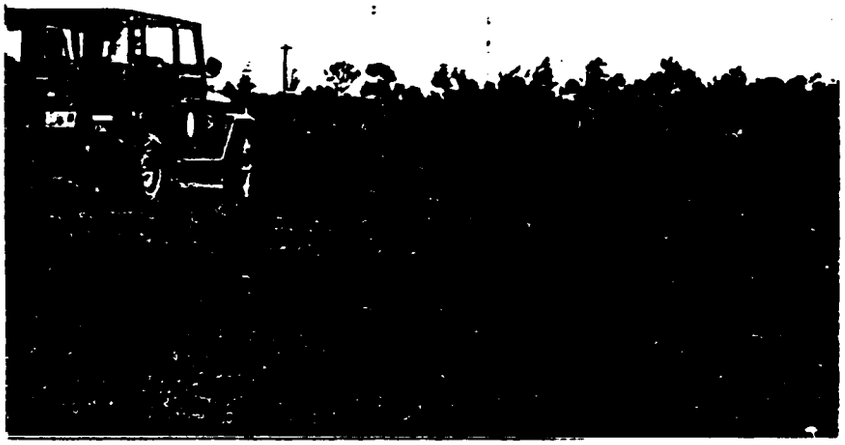

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REDDISH-BROWN MOTTLED CLAY DEPOSITS ON MAP

A - Sample Pit near Gachlau
261179A

B - Sample Location 261179B
at Derikan (airport)

C - Surface Exposure by the
Road near Derikan (airport

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YAP

Yellow-brown clay, equivalent to unit 12 of Map 4 of the 'Military Geology of Yap'. Sample location 271179A near Numnung.

Medium brown clay. In sample hole 271179B near Murru on Gagil-Tomil. Occurs beneath 35 cm of limonitic gravel.

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a depth of at least 65cm. Between the crossroads and the lake there is an area of at least 3 hectares (7.4 acres). Assuming all of it would be available for development as a raw material source and the thickness of 0.65m to be maintained over that area, there would be at least 20,000m^3 of clay available here alone, adequate for about 1 million bricks. However, this clay extends over a much greater area, around the airport and south into Kanifay and Giliman and the depth to which it could be extracted, i.e. the water table level, is 30 feet according to the Military Geology report. Hence, the reserves would be inexhaustable. It is easily accessible and has either no vegetation or else uncultivated grassy and wooded covering with no other overburden to remove. Sample No. 261179B.

The same clay was sampled 300m north of Gachlau. Sample No.261179A (This reddish-brown mottled clay feels less plastic than the previous, yellow-brown, clay and may be better suited to brick production by hand moulding than extrusion moulding or pottery. Obviously, in considering the location of any ceramic factory in this area, from the raw material viewpoint, favoured locations would be where the two clays are within close proximity to each other, as for example, around the road from Derikan running eastwards for about 1km towards Colonia, and to the south of Deloy and Gitam).

This reddish-brown mottled clay will also be present above the Tomil Volcanic Formation on Gagil-Tomil.

Medium Brown Clay. Occurs only, as far as is known, in and around the villages of Maki and Murru on Gagil-Tomil. Lying on the surface are nodules of brown limonite, $Fe_2O_3.nH_2O$, and these extend down to a depth of 35cm and give way to at least 75cm (and up to 27 feet according to the Military Geology report) of uniform, stiff brown clay which is fairly plastic and free from stony material. It is easily accessible, both for vehicle access and to remove the loosely consolidated layer of limonitic gravel. Several hectares appear to exist for potential exploitation and of adequate thickness for supplying raw material for medium scale ceramic production. Even if not found to be useable on its own, this clay is situated only 10km from the area where the first two clays occur together, between Derikan and Gitam, and could

prove to be a useful additional raw material for adjusting the blend of clays to the optimum performance. Sample No.271179B.

(Details of the sampled locations, etc. are given in Appendix V)

3.1.2. Palau. As noted previously, in Section 2.1.2., from the previously available geological information about the clays of Palau there are three main sources of clay available:

the weathered volcanic tuff and breccia,
the sedimentary clay with lignite,
the alluvium.

During the field work, in fact only the various occurrences of the sedimentary clay, or 'Airai Clay, named from its type locality, and the clay used beside the Ngarsuul pottery, which may be alluvium, were examined or sampled. It was found by the field geologist, that at least three distinct clay horizons occur in the 'sedimentary clay with lignite'. All three of them occur in the same locality just south of the airport in Airai and two of them were also represented by closely similar material in places such as Oikul, Ngatpang and Ngerasch island.(Note: Oikul was referred to as 'Goikul'by the Japanese and'Ngerassa'has been used for Ngerasch). (The'weathered volcanic tuff and breccia' was not investigated. It is a possible useful additional raw material, occurring near to the more important sedimentary clay and it is likely that, as reddish-brown lateritic soil, it is similar to the samples nos. 261179B and 261179A collected from the 'reddish-brown mottled clay' above the Tomil Volcanics Formation of Yap).
In view of the very obvious attraction, from the raw material viewpoint, of the Airai airport location as well as its possible convenient and practical situation for establishing any proposed future ceramic production for Palau, the Palau field work is here summarized on the basis of the raw materials occurring there and referring, as appropriate, to the other locations where the same clay seems to occur. In particular, the location is the erosion scar ,seen on the aerial photograph reference '36 4-85', one of the series being used by the present U.S. Soil Survey team in Palau (Mr. Neil Babik and Mr. Chris Smith). It lies approximately 160m due north of the still surviving gable of the west end of the bombed Japanese building and approximately 330m from the airport

windsock. (See Appendix VI for more precise data on all the Palau sample locations and clay materials, etc.)

White and red mottled Clay. Is the uppermost clay layer at Airai airport, occurring beside the road just west of the bombed Japanese building and further north, to 110m south-west of the windsock, where it is at least two metres thick. It is of medium plasticity or less probably as it seems to be kaolinitic.It is easily accessible, with no overburden or only grass, ferns and a few pandanus. Sample No.031279A1 (at the top of the erosion scar), 031279B1 (110m south-west of the windsock by the airport building), and the same material, or closely equivalent is 301179A (from an auger hole,60-90cm depth, 35m north-west of the dam at Oikul) and the deposit of clay on Ngerasch island, exposed between the dock and the 1939 kiln of the structural clay products factory, is very similar. Allowing for some 150 feet of ground to be taken south of the present airport for the projected new runway, there are some 5 hectares or more of this clay at Airai airport, say 50,000 m^3 and at Oikul probably more than the 23,000 metric tonnes reported proved by the Japanese in 1940, as well as the material left at Ngerasch and elsewhere.

Grey Clay.Is the middle of the three clays at Airai airport, and is exposed in the erosion scar immediately beneath the main (70-80cm thick) lignite bed. It is pale grey, both at the weathered surface and with depth, uniform apart from some carbonaceous matter, plastic and tight. Is probably the grey, plastic clay found by the potter Vitarelli and the NY State University to be good for throwing on a potter's wheel though it does not appear to be so plastic as to warrant the name 'ball clay' which they suggest it is. (Ball clay is probably the most valuable raw material, in terms of its moulding characteristics and its ability to upgrade otherwise poor clays when blended with them. Its presence at Airai airport,(and possibly also at Ngatpang), is one of the reasons why the field geologist considers that locality to be so suitable for a future ceramic industry, and may also account for the fact that pots were made, in the past, at Ngatpang). At Airai it is about 1m thick, and is exposed in various gulleys in the area between the airport building and the bombed

A

PALAU

A - View looking westwards up the erosion scar near the airport in Airai. Mr. Hank Takaeo is standing on the lower of the two beds of 'Grey Clay Weathering Green' of sample location 051279A3.

B - The same erosion scar viewed from the top, looking east. The uppermost clay, the White and Red Mottled Clay is in the foreground.

C - The sample location for White and Red Mottled Clay close to the airport building in Airai Sample no. 051279B1

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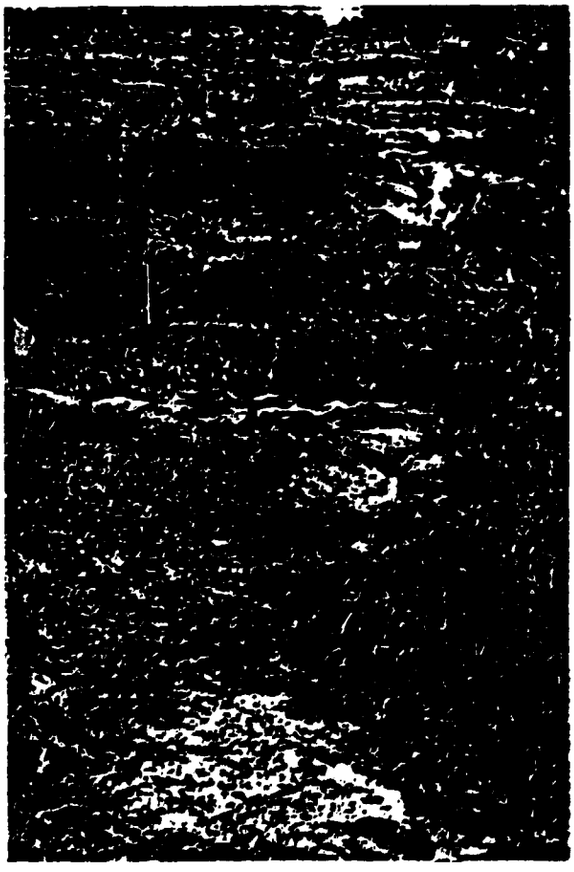
B



C

PALAU

The waterlogged and poorly exposed location where the plastic clay used to be taken from close beside the Ngarsuul Pottery at Kless.

White and Red Mottled Clay

Location of Sample no. 30179A at Oikul.

Lignite Bed

The good exposure lies 80m south of the erosion scar of location C31279A between the airport and the bombed Japanese building in Airai.

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PALAU

Showing the difficulty of finding good exposures of clay in the area around the municipality of Ngatpang.

Grey Clay

Location of sample no. 3011798 near Ngatpang.

Seeking another occurrence of clay near Ngatpang showing the thick vegetation in this area close to Maromado Bay.

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building and to the east of the stream, say 10 hectares, or about 100,000 m^3. Accessible after removal of the overlying white clay and the lignite, both of which are consumable raw materials. Sample no. 031279A2 (from the gulley near the top of the Airai airport erosion scar). Sample no.301179B (near the municipality of Ngatpang) is probably similar.

Grey Clay Weathering Green. Is the lowest situated of the three clays at Airai airport and as not found elsewhere. It occurs as two main beds each about 1½m thick and separated by a layer of limonitic clay, exposed in the lower part of the erosion scar. On the surface is pale green but 10cm beneath it it becomes medium grey and starts to show relic structure of the underlying volcanic breccia from which it has weathered. Hence this is a residual clay, whereas the other two are sedimentary in origin, it has coarser particles present and feels much less plastic. After a period of weathering to promote breakdown of those particles, and so increase slightly its plasticity, this clay could be useful, like the red, lateritic soils north of the airport, in lowering the drying shrinkage of the other clays, if that was found to be necessary, and to modify their behaviour in other ways as well. Not readily accessible except where the overlying clays and lignite have been removed, but exposures occur in some gullies besides in the erosion scar.(Due to the only slight,approximately 5^{o},dip to the north east, as this unit is dug the volume of overburden to be removed would increase and make it difficult to obtain unless the overlying beds were being worked as well at a no less rapid rate). Sample no. 031279A3 (from the higher of the two green beds in the erosion scar).

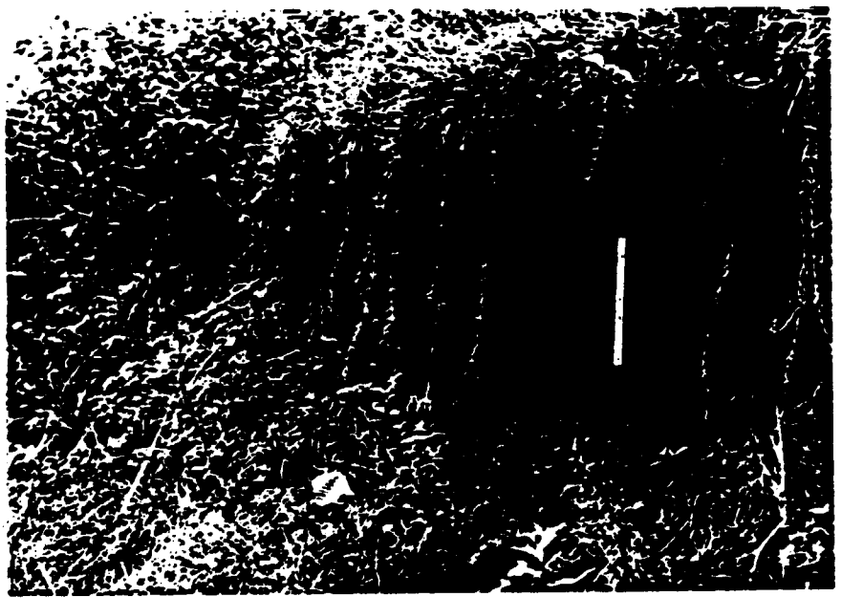
Alluvium. This type of clay was not seen near Airai airport but the map indicates it occurs in the Airai district. It may be the plastic clay 20m to the north of the Ngarsuul pottery at Kless. However, the field geologist found during the visit there that it was so poorly exposed, and beneath surface water as well as tall grass, that it was not possible to obtain a satisfactory and representative sample. It was virtually impossible to make a reasonable estimate of how much of that clay occurs at Kless.

3.1.3. Truk. Compared with the clays on Babelthuap in Palau, there are only two clay formations on Moen and Dublon and, although they are of great extent and readily accessible, they do not appear to have the interesting ceramic properties of the Palau raw materials. More data on the locations is in Appendix VII.

Yellow-Brown Clay Free from Stones - Truk Clay. Covers about 23% of the volcanic uplands of Moen and Dublon. Good exposures were found at Epinup (sample no.071279A, from the road cutting opposite the house of Mr. Ermut Manaka) and at Levi, along the muddy road, impassable to vehicles, running from Truk High School to Tunuk. At Epinup there is at least 2m of yellow-brown, slightly plastic clay, free from stones, under approximately 20cm of dark grey earth soil with ferns, coconut trees, etc. This clay extends south west from Epinup for about 500m and is at least 1m thick along the road; apart from where there are houses, it is readily accessible for easy development as a source of raw material. It appears to be inadequate for other than possibly the making of solid bricks by hand moulding. Available reserves are enough, on Moen at least, for small scale production of bricks, etc.

Red and Brown Clay with Stones - Truk Stony Clay. Apart from the presence of hard stones which would have to be removed, this clay is similar to the previous one but has slightly more plasticity and hence more likely to be useable in simple pottery making and for some structural clay products. The available reserves are substantial as it covers more than half of the area of Moen and Dublon, according to Maps 13 and 14 of the Military Geology of Truk, though its thickness varies greatly, between one and 30 feet. The one exposure sampled (sample no. 071279B, from below the house of Mr. Frank Nifon in Sabou, 650m south of the Logan Memorial Church) showed 50cm of red and brown clay, fairly plastic, with some roots and some small stones, beneath 30cm of top soil. Owing to the built up nature of the area this sample location is not available for development as a source of raw material. Another exposure was seen to the north of the radio mast where over 1m of a dark grey clay is exposed.

Location of sample no. 071279A near Tpinup, opposite the house of Mr. Ermut Manaka.



Another roadside exposure near Tpinu

Impassable muddy road in Truk Clay at Levi near Tunuk.

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The impression gained from the field work on Truk tended to the view that the raw materials there are not suitable, or else only for simple items such as bricks, which may account for there being no record of previous ceramic activity there.

3.2. Other Potential Raw Materials for Building Material Use

The primary purpose of the mission was to investigate the clays available for ceramic uses. In passing, some other sources of building material were noted:

3.2.1. Limestone. Fairly substantial quantities of old (not living) reef limestone occur at the south end of Babelthuap and on Koror in Palau. The harder stone looks suitable for burning in a simple vertical shaft kiln to make building lime, i.e. for mortar and whitewash, etc. However, the site selected for quarrying would have to be well concealed so as not to cause unacceptable damage to the natural beauty of the area.
Apart from living coral reefs, there appear to be no limestones available on Yap islands proper or on Moen and Dublon in Truk.

3.2.2. Basalt (natural building stone). A large quarry has been opened in the thick flow of basalt igneous rock close to the present airfield runway on Moen in Truk. It is being used for aggregate for the construction of the new,longer runway there. In the lower part of the quarry face, the basalt is columnar and yields large size blocks often with nearly flat faces. There is at least one private house, in the area of the District Headquarters, whose walls are built from this rock. It appears to be a more appropriate material to use than the ubiquitous imported corrugated galvanized iron sheets, that are used throughout Yap, Palau and Truk for the walls and roofs of houses. Obviously the Moen basalt would be too heavy and the transport cost too high for it to be utilized other than on Moen.

4. SAMPLES AND FURTHER TESTING

As one of the objectives of the mission, samples were taken as deemed appropriate of those clay raw materials which appeared to have the greatest significance for the possible future establishment of ceramic industries in Yap, Palau and Truk. A decision on what testing should be done, and where, will be made in consultation with

the SIDFA at UNDP, in Suva. In each case, not less than 10kg of representative material was collected, from one exposure or borehole, placed in double plastic bags and labeled with the sample no., the clay type and the location.

4.1.The Samples.

4.1.1.Yap. Sample No.261179C. Yellow-brown clay.Derikan.
" " 271179A. " " " .Numnung.
" " 261179A. Red-brown mott.clay. Gachlau.
" " 261179B. " " " " . Derikan.
" " 271179B. Medium brown clay. Murru.

These five samples are held by Mr. Philip Rrig in the office of Resources and Development, in Colonia, Yap.

4.1.2.Palau

Sample No.031279A1. White/red mottled clay.Airai(airport).
" " 031279A2. Grey clay. Airai (airport).
" " 031279A3. Grey clay weathering green. Airai (airport)
" " 031279B1. White/red mottled clay.Airport building.
" " 301179A. White/red mottled clay.Oikul.
" " 301179B. Grey clay. Ngatpang.

These six samples are held by Mr. Isamu Towai in the office of Land Management in Koror, Palau.

4.1.3. Truk.

Sample No.071279A. Truk Clay. Epinup.
" " 071279B. Truk Stony Clay. Sabou.

These two samples are held by Mr. Simion Leo in the office of Land Management on Moen, Truk.

Before they can be transported, these samples have to be placed, still within their plastic bags, into small open top steel drums or other secure metal containers, free from grease, etc.

4.2. Laboratory Testing.

Assuming that the most likely products to be produced, at least initially, from these clays will be pottery and simple structural clay products such as bricks and possibly roofing tiles, the field geologist recommends that any

programme of laboratory testing proposed for these samples should determine the following physical characteristics. (Chemical and mineralogical data would be instructive but of far less practical significance) :-

Grading. Sieve analysis and sedimentation (Andreasen pipette) analysis to show the following size fractions:

Gravel	:larger than 2.4mm
Coarse sand	:2.4 to 0.2mm
Fine sand	:0.2 to 0.02mm
Silt	:0.02 to 0.002mm
Clay	:smaller than 0.002mm

The fine sand, silt and clay percentages are then plotted on a Winkler Diagram to indicate possible suitability for pottery, tiles, etc.

Plasticity. Determination of the Atterberg Plastic and Liquid Limits, and by difference the Plasticity Index, by means of a Casagrande apparatus, etc. By plotting on a graph of PL v. PI, as proposed by Bain, the likely suitability for moulding pottery, bricks, etc., can be judged.

Drying Shrinkage. Determination of the drying shrinkage (DS) at successive reducing water contents as drying proceeds, ending with drying to constant weight at 110°C. Hence obtain the Bigot Curve and the Drying Sensitivity (DSe) :-

$$DSe = \frac{W_m - W_c}{W_c}$$

where W_m is the percentage of water needed for moulding and W_c is the 'critical' water content after which no further drying shrinkage takes place.

When DSe is less than 1, the clay is said to be 'not drying sensitive', between 1 and 2 it is 'sensitive' and above 2 it is 'very sensitive'.

Green Strength. The flexural or bending strength of dried, unfired test specimens, 120 X 20 X 20 mm.

Firing Schedule. Determine the likely optimum firing temperature and firing characteristics of the clay by firing in a kiln test specimens, preferably at six different temperatures, otherwise four or at least three, as indicated, and note, for each temperature, the properties shown in the column on the left:

Ideal range of temp:	850	900	950	1000	1050	1100 °C
or :	850		925	1000		1075
minimum tests :	875		975			1075
Sound test (ring)						
Appearance (colour, etc.)						
Firing shrinkage						
Water Absorption						
Compressive Strength						

In the opinion of the field geologist, a good guide to the suitable tests for evaluating clays, especially for structural clay products manufacture, is given by Vladimir Lach (later revised by T.Chvatal) in his paper 'Testing and Evaluation of Brick Clays' for the August 1968 Interregional Seminar on the Development of Clay Building Materials Industries in Developing Countries, UNIDO document ID/WG.16/2, July 1968.

4.3. A Suggested Alternative Approach

It is understood that there is provision made in the project budget for up to US$10,000 to be available for the laboratory testing of the samples. The field geologist fully supports the proposal to carry out thorough testing of raw materials before any decision is taken which leads to a major capital investment, such as for a medium or larger scale factory with the importation of machinery and building of kilns costing more than, say US$250,000 and as much as US$3million or more. Such testing is essential to avoid the risk of losing the capital investment due to inappropriate raw materials being selected and processing of bulk quantities on an existing plant is usually

mandatory.

However, in view of the relatively small size of the local market and the fact that,with steeply rising fuel costs for transport,bulky items such as bricks and other building materials will be made in comparatively small factories located on raw material deposits close to the centres of consumption of the products, the field geologist suggests that the proposed laboratory testing may not be appropriate and that the money could be spent more profitably, socially and economically, in other ways. In addition, discussions with TTPI government personnel have shown a marked preference for the establishment of smaller scale, low capital, rural manufacturing units in the case of these projected ceramic activities on Palau,Yap and Truk.

Further investigation of the clays in Palau is fully warranted and those selected in Yap and Truk are also worth trying out. The field geologist proposes that this further work be done locally, probably based in Palau, with field tests in Yap and Truk if the tests done on those samples in Palau are promising. The many reasons why this approach would be more appropriate are listed below.

4.3.1. Advantages to Local Evaluation of the Clays

The time factor. Testing by overseas laboratories takes a long time - more than two years in the U.S.A. Provided a suitable candidate can be recruited, with the facilities available in Palau results should be available in one year or less.

Scale Up Problem. Local tests would be on 'full scale' specimens. Laboratory testing is on small specimens and the raw material still has to be proved to be suitable for actual production conditions.

Communication. Local testing means that the performance of the raw materials and the process used can be demonstrated directly to local government officials and entrepreneurs.

Funding. Part, at least, of the 'testing' budget will be spent within the Trust Territory and some will enter the local economy through the pockets of local people employed to assist with the work.

Local Facilities Exist. A fully equipped pottery, requiring possible minor items such as pyrometric cones and diesel for the generator, exists at Kless in Babelthuap (the Ngarsuul Pottery) and items such as kickwheels and firebricks for reconstruction of the pottery kilns exist at the now defunct pottery at the Palau High School. (There are two kilns intact at the Ngarsuul Pottery). See the end of Appendix VI for an inventory of the items seen at those two sites.
It would be an easy matter to construct a simple brick mould with which to make sand moulded bricks for firing in the pottery kilns.
A much more convenient location for the 'Ngarsuul' pottery would be close to the Airai (airport) clays and a suitable site for it may be the Seventh Day Adventist School nearby, if arrangements can be agreed to transfer it from Kless. No use has been made of the pottery by the Kless people since at least June 1979.

In order to carry out the local testing properly, due to the absence now of any one with the requisite skill in Palau it would be necessary to recruit a UNIDO Associate Expert, or a U.K. Voluntary Service Overseas or U.S. Peace Corps volunteer to do the work, under the supervision, periodically, of a visiting UNIDO Adviser or ceramic specialist from Guam or Hawaii.

It is strongly recommended to the authorities in Palau that all precautions be taken to ensure that the pottery equipment and materials at Kless are not permitted to suffer the same fate as did those at the Palau High School. The existence of that pottery, either at Kless or preferably moved to near the airport, is a considerable asset for use in further evaluation of the clays not only of Palau but of other locations in Micronesia as well. Undoubtedly, the ceramic technologist, proposed for executing Phase III of this Project, will find it of the greatest convenience to be able to carry out small scale investigations with those facilities.

It is suggested that the person best able to decide whether the work of the second phase should be carried out in a ceramic laboratory in, for example, Australia or the Philippines, etc., would be the SIDFA for the region, Mr. Dello-Strologo, who himself has much experience in this field. One factor not clear at this stage is how true it is, as has been suggested, that the Ngarsuul Pottery is the 'property' of the village of Kless. It is recommended that the appropriate authorities, presumably in Palau, make careful investigation to determine how easy, or difficult it would be to re-locate that pottery in Airai, as close as possible to the source of clays there, near the airport.

5. OTHER INFORMATION WHICH MAY BE RELEVANT TO THE PROJECT

In the course of the mission, the field geologist observed various other factors which could affect the development of pottery and small scale manufacture of structural clay products in Yap, Palau and Truk.

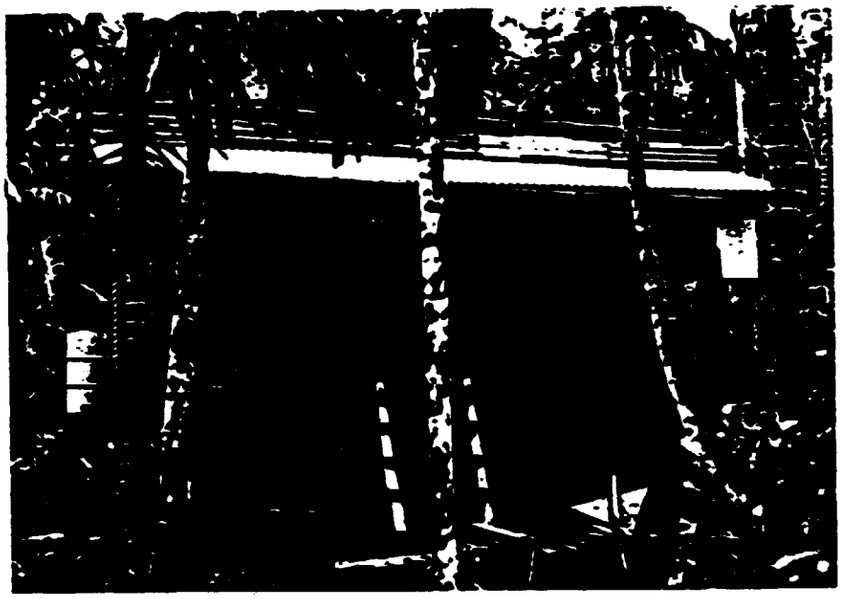
5.1. Imported Building Materials

With the exception of structures such as the 'men's houses' and fishermen's boat houses, new houses are using entirely imported materials. The cement for the floors comes from Taiwan or Japan and costs the local builders, in Koror, for example, US$7 per 40kg bag, i.e. US$170 per metric tonne, which is expensive. The corrugated galvanized iron sheets for the walls and roofs is USG 26 guage and comes from Japan. The frame is made from imported larch and Douglas fir. The aluminium and glass for the louvre windows is imported.

There is production of hollow concrete blocks from small factories in Koror, Colonia (Yap) and on Moen using the imported cement and coral sand. The blocks sell for 65 to 110 cents each.

There is no production of building lime in Micronesia although deposits of limestone, which may be suitable, exist in Saipan and Palau.

UTILIZATION OF IMPORTED CORRUGATED GALVANIZED IRON SHEETS IN HOUSING

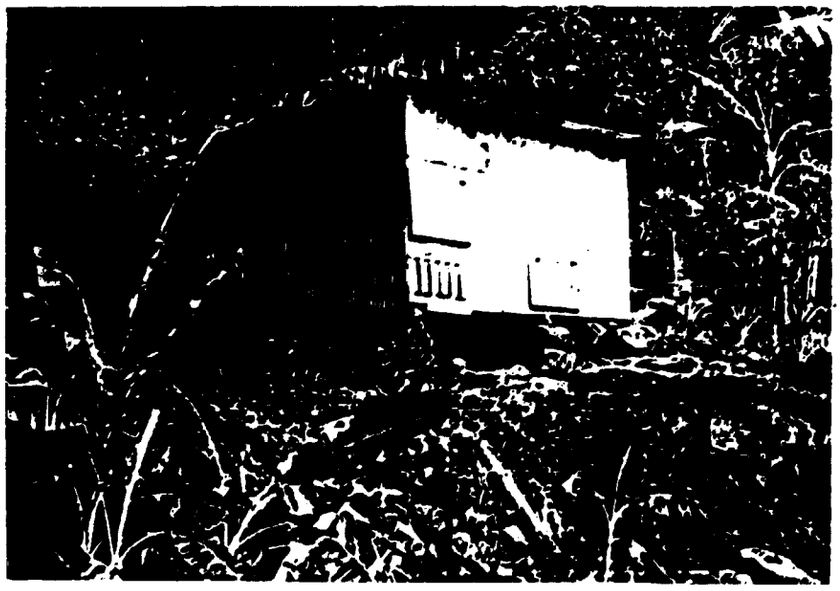


YAP

A rural house in Marru, in Gagil-Tomil.

PALAU

A new building erected at the Ibobang School in Koror.



TRUK

A house by the shore on Moen, between Or and Supuk.

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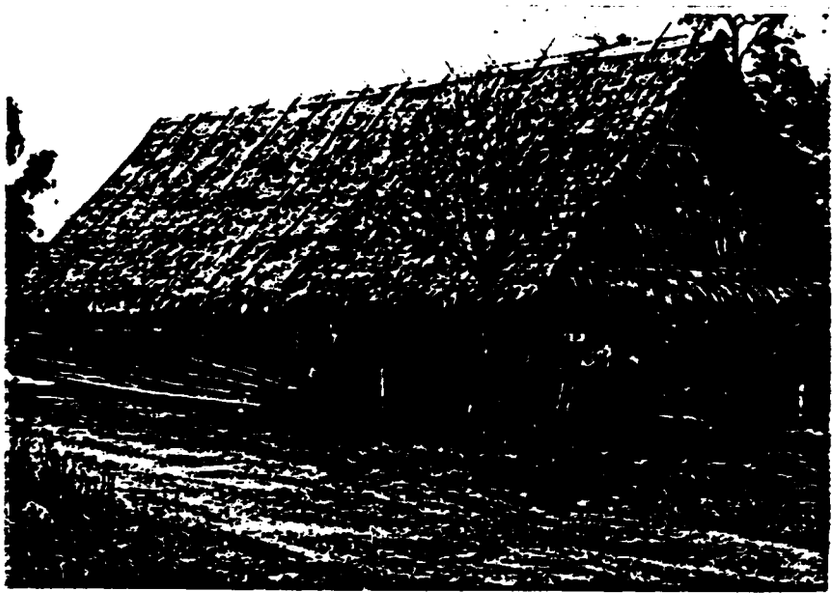
A -

B -



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C -

UTILIZATION OF INDIGENOUS BUILDING MATERIALS

A- Dormitory House at the Ibobang School in Ngatpang, overlocking Karamado Bay in Palau.

B- Fishermen's boat house near Ngof, south- east Yap.

C- Detail of the gable of the roof of the boat house at Ngof, Yap showing use of bamboo, palm leaves and precast concrete columns.

5.2.Little Indigenous Manufacturing Skill Exists

At the present time there is no-one engaged in the making of fired clay products that the field geologist has learned of in Micronesia. The two men who assisted the foreign potters at Ngarsuul Pottery in Palau have either left the island or are engaged in other courses of study. Since 1939, it appears that all ceramic activity was initiated and largely carried out by foreigners.

In addition, apart from some production of concrete blocks, the field geologist saw no evidence of any industrial production as such being carried out in the islands visited. The tourist and 'craft' items on sale in hotels, etc. appear to be imported.

5.3.Local Entrepreneurs

There are a few Micronesian people, such as Mr. Demei Otobed in Palau and Mr. Quirino Mendiola of Ponape, who wish to promote industrial enterprises and are interested in the possibility of manufacturing bricks and other building materials.

5.4.Fuels

The fuel used in the pottery at Ngarsuul (Kless) was diesel, through a Japanese oil burner. It seems highly likely that the cost of diesel will become too high, along with other imported fossil fuels, for it to be feasible for use in pottery and brick production.

At present there is no exploitation of the reserves of timber which appear to be fairly abundant on most islands. Wood is a traditional fuel for burning clay bricks and it is suggested that mangrove and other timbers should be used in future. In addition, and possibly as a wider ranging safeguard to establish fuel reserves generally in Micronesia, fast growing tree species, perhaps including the Giant Ipil-ipil which has been so successful in the Philippines in the past 12 years, should be planted now.

In Palau, a further important advantage of the Airai airport site as a potential centre for ceramic production,

is the existence there, close to the surface, of one or more beds of lignite up to 1m thick. As proved by the Okinawan brick and tile maker on Ngerasch in 1939-42, when dried this lignite, which is a type of low grade coal occurring also in Ngatpang and Oikul, is a valuable supplement to wood as a fuel for firing the kilns.

5.5. Seismic Activity

Contrary to some statements made, the level of seismic activity in Yap, Palau and Truk is too low to influence the design of buildings and the choice of building materials. However, some precautions, especially in the materials and fixing of the roof, have to be taken to cope with the occasional typhoons that pass through, especially in the western Caroline Islands.

6. RECOMMENDATIONS

6.1. Palau Clays

A good variety of clays exists on the island of Babelthuap in adequate amounts for supplying raw material to small or medium scale ceramic factories of different types such as pottery and structural clay products. Some of these clays have been proven already to be suitable for such uses.

The most accessible and best exposed deposits occur between the airport building and the old bombed Japanese building in Airai. It is recommended to consider that locality first, as being appropriate in many respects, for the siting of any new ceramic production centre in Palau.

6.2. Yap Clays

At least three types of clay deposit, all readily accessible, are present on Yap in amounts sufficient for establishing small to medium scale production of fired clay products. From the available soils engineering data and observation in the field, they appear also to be of suitable quality, possibly when blended, for at least the making of bricks as well as the revival of the casting of pots. It

is recommended that the three samples of clay from Yap should be tested, after suitable preparation, by moulding and firing simple pots and bricks to examine their quality. The facilities of the pottery in Palau could be used for this purpose if the samples are not to be sent to an overseas testing laboratory.

6.3. Truk Clays

Clay is plentiful on both Moen and Dublon, for example, but the two types of deposit do not appear to have good moulding characteristics and it is possible that only hand moulded bricks can be made with them.

As with the Yap clays, the samples could be moulded and fired in the pottery in Palau. If there is strong local interest, some bricks should be made locally, by hand, and a simple clamp constructed for firing them with wood as fuel.

6.4. Testing

The present proposal in the Project Document is for the 13 samples to be despatched for testing in a competent ceramic laboratory. There are many reasons for an alternative approach which is to test them 'by hand', on the 'full scale' using the facilities that already exist in Palau.

The field geologist is in favour of doing the assessment work locally and suggests that the SIDFA for the Region is well placed to decide this point, in view of his own technical and personal interest in this project.

6.5. The Pottery in Palau

At the present time, there exists at Kloss in Palau a complete pottery, with all basic facilities, needing little attention for it to become operational. Other valuable items, also not being used, exist in the Palau High School. These constitute a most valuable asset for facilitating any future revival of ceramic industry in Palau as well as for the evaluation of clays from other parts of Micronesia.

It is strongly recommended that action is taken now by the appropriate authorities to ensure that all the items now in the pottery at Kloss are safeguarded and that the

same fate does not befall the Kless (=Ngarsuul) pottery as did the one at the Palau High School.

The site at Kless does not appear at all suitable for a pottery. A more appropriate location would be in the vicinity of the airport in Airai. Here the best source of clays exists, as well as lignite fuel, the communications are good and the location is neither too close to Koror nor too far.

6.6. The Ceramic Technologist

The person to be recruited for Phase III of the project should be well aquainted with methods for the making of bricks, both by hand as well as by small, efficient mechanized plants, and pottery. Preferably he/she should be able to demonstrate, with the assistance of an associate expert, U.K. Voluntary Service Overseas or Peace Corps volunteer, how to make pottery and also to make bricks and tiles by hand and to fire them, for example in a small clamp. There would be, in addition, the work already specified in the job description of assessing the market and type of industry that should be introduced.

Acknowledgements

During the mission the field geologist received much assistance from TTPI government personnel in Saipan, particularly from the Department of Development Services, and he thanks both the Administrator, Mr. Lazarus Salii, and Mr. Kozo Yamada, Director of the Bureau of Resources, for the facilities they provided.

In Yap, much help was provided by Mr. Philip Rrig, acting on behalf of Mr. Sam Falanruw, Director of Resources and Development.

In Palau, thanks are due to both Mr. Sal Ongrung, head of the Economic Development Office, and Mr. Idesair Techur, head of the Land Management Office, for roviding the co-operation of Mr. Hank Takawo and Mr. Isamu Towai in

the field work on Babelthuap and in transportation by land and sea.

In Truk, Mr. Simion Leo of the Land Management Office acted as guide to the soils occurring in the west and south parts of Moen.

Finally, much useful advice and information was provided in Suva, Fiji, by Mr. Ingolf Schuetz-Mueller, ARR in the regional office of UNDP there.

UNITED NATIONS

APPENDIX I

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION

UNIDO

JOB DESCRIPTION
SI/TTP/79/801/11-01/32.1.B

Post title	Field Geologist
Duration	Six weeks
Date required	As soon as possible
Duty station	Saipan, with travel to Palau, Yap and Truk
Purpose of project	To assist in the investigation of the potential for a local ceramic industry

Duties

The expert will be attached to the TTPI Government. The expert will specifically be expected to:

1. Study available information on clay deposits (and related test results) in the Palau, Yap and Truk Districts;
2. Carry out a geological survey of clay deposits in the three districts with the logistic assistance of the Public Works, Department and other District Headquarters facilities;
3. Ascertain the quantity, depth and consistency of the clay deposits and their accessibility to the Centre;
4. Collect representative samples from the surveyed deposits for the laboratory testing:
5. Prepare a report on his findings and recommendations.

The expert will also be expected to prepare a final report, setting out the findings of his mission and his recommendations to the Government on further action which might be taken.

..../..

Qualifications Field Geologist with experience in clay exploration and knowledge of technologies of clay products manufactures.

Language English

Background information The Trust Territory of the Pacific Islands (TTPI) consists of over 2,000 islands covering about 1,300 square kilometers of land over an area of over 7,500,000 square kilometers of ocean. However, only 84 of the islands are inhabited with a total population estimated at 120,000 in 1978. Most live in the districts Palau, Yap, Truk and Ponape. The Headquarters of the TTPI Government is located in Saipan in the Mariana Islands.

At present the building pattern in Micronesia seems to favour the use of reinforced concrete to suit the US Federal Standards for anti-cyclone anti-seismic conditions. However, with the gradual introduction of independence via the establishment of "The Federated States of Micronesia" and the termination of the trusteeship which the US Administration has announced by 1981 the use of local building materials, including bricks, might become a matter of primary concern. The production of pottery for sale to the ever increasing number of tourists as well a local manufacture of ceramic filters represent other promising possibilities.

APPENDIX II

TIME SCHEDULE FOR THE MISSION

Date		Event/Location
November	11th 1979	Departed from England.
	12th	Briefing in UNIDO, Vienna.
	15th-16th	Briefing at UNDP in Suva, Fiji.
	18th	Arrived in Guam, in transit.
	19th -23rd	In Saipan for briefing by TTPI Government. Prolonged by three days due to cancellation of flights.
	24th-27th	In Yap.
	28th -	
December	4th	In Palau.
	5th	In transit in Guam.
	6th-11th	In Truk, prolonged by one day due to a flight cancellation.
	12th-17th	In Saipan for report writing and final discussions with TTPI Government staff.
	18th	In transit in Guam.
	19th-21st	In Fiji for de-briefing.
	22nd	Assignment time ended with departure from Fiji.
	23rd-30th	In Indonesia for private visit to project INS/74/034 at the invitation of the Director, Directorate of Building Research, Bandung.
January	3rd-4th 1980	Debriefing at UNIDO, Vienna.

APPENDIX III

COUNTERPARTS AND SOME OTHER LOCAL CONTACTS

SAIPAN

Counterpart: Mr.Ermas Ngiraelbaed. Acting Chief of Lands,TTPI.

Contacts: Mr. Kozo Yamada. Director of the Bureau of Resources.
Mrs. Elizabeth Udui. Chief Economist.
Mr. Michael Dean Rody. Director,Office of Planning and Statistics.
Mr. Nahum Benzeevi.UNDP Economic Adviser.

YAP

Counterpart: Mr. Philip Rrig, deputizing for Mr. Sam Falanruw, Director, Resources and Development.

Contacts: Mr. Charles D.Jordan. State Planning Officer.
Mr. John Mangefel. Governor.
Mr. Hillary Tacheliol. Lt.Governor.
Mrs Margie Falanruw.Yap Institute of Natural Sciences.
Mr. Henning Gatz. Economic Development Adviser.

PALAU

Counterparts: Mr. Isamu Towai. Land Classification Technician.
Mr. Hank Takao. Economic Development & Resources.

Contacts: Mr. Kim Batcheller. District Administrator.
Idesair Techur. Land Management Officer.
Mr. Sal Ongrung. Economic Development Officer.
Mr. James Ngirmechesengel. Former pottery trainee.
Mr. Demei Otobed. Chief Entomologist.
Tina Rehuher. Director of the Museum.
Mr. Ludwig Mayer. FAO cattle expert.
Mr. Chris Smith. U.S. soil survey scientists.
Mr. Neil Babik " " " "

TRUK

Counterpart: Mr. Simion Leo. Land Management Officer.

Contacts: Mr. Erhard Aten. Governor.
Mr. Redley Killion. Economic Adviser.
Mr. Eric Thompson. Economist for the legislator.

APPENDIX IV

RESULTS OF CERAMIC TESTS ON PALAU CLAYS BY NY STATE UNIV., ALFRED

Summary of the Significant Information, with other Comments.

Sample No.	Location	Results
A-1	Ngerasch but listed originally as Ngatbang.	Light grey clay, low Fe_2O_3, not good for throwing, suitable for ceramic filters -absorbs, fires white.
B-1	Ngerasch	Not good for throwing, OK for structural clay products. Fires red, moderate absorption, not much cracking.
B-2	Ngerasch	As engobe or for high porosity uses. Not good for throwing. Fires white above 1116°C.
C-1	Ngerdmau	For bricks or coloured slips and engobes. Not good for throwing. Fires OK to a dark red-grey.
D-1	Ngarsuul	Dry pressing and other structural clay products. Very short, fires red, OK.
F-1	Airai	According to Vitarelli, the Airai clays are grey, very plastic and tight and contain lime. NY State Univ. analyses show very little lime present. F-1 is good for throwing, sculpture, fires white to pale yellow.
F-2		F-2 is like a ball clay, too plastic on its own - use to add to a non-plastic clay. D.S.=13%, fires to a pale blue-grey or off-white.
F-3		F-3 is very good for throwing. D.S.=9%. Some tendency to crack. Fires yellow.
(NL) A-1	Ngatbang	Throws fair. Strong, good handling body, could be mixed with F-2. D.S.=11.5%. No cracking. Fires OK to a pale red or pale grey-red.

Notes: The sampling was done by Sandy Vitarelli and Hank Takawo. See report of Vitarelli for August 1977 for some location information and sketch maps.

* Address: New York State College of Ceramics, Alfred, NY 14802, USA.

APPENDIX V

INITIAL REPORT BY NEVILLE R. HILL, UNIDO FIELD GEOLOGIST

on

POSSIBLE CLAY DEPOSITS FOR CERAMIC USES ON YAP PROPER

PURPOSE OF THE MISSION

Briefly, the main duties were to study available information, carry out a geological survey of the clay deposits, ascertain their depth, quantity and consistency, collect any samples necessary for laboratory testing and report on the findings and recommendations.

PREVIOUSLY AVAILABLE INFORMATION

1. History of Ceramic Activities on Yap. It was known that in at least one location, women used to make pots by coiling the clay; those people are no longer alive and the knowledge of the clay used has been lost. During the mission to Yap, it was learned that pots were made in Gitam, Ngof and Gachlau. There is at present no ceramic production on Yap proper. There is a small factory making concrete blocks, reputed to cost US$1.10 each.

2. Geological Data Available. Unlike Palau, no previous sampling and testing of clays has been carried out recently on Yap. Soon after World War II, a very comprehensive report on the soils, etc. of Yap and other Micronesian islands was compiled which gives plasticity, shrinkage and granulometric data for the soils at various locations together with a series of maps. See "Military Geology of Yap Island. Caroline Is.". Intelligence Division, Office of the Engineer, HQ U.S. Army Forces, Far East and Eighth U.S. Army (Rear), 1957.

In "Micronesian Minerals" by Gabriel Dela Cruz, Dept. of of Resources and Development, TTPI, Saipan, there is no mention of clays on Yap; the only similar material mentioned is bauxite, though not of commercial interest due to its high silica content.

AREA SURVEYED

In the two days available for field work, the following areas were visited by four wheel drive vehicle, in company with Mr. Philip Rrig of the office of the Department of Resources and Development:

From Colonia westwards to the airport and then south to Gachlau.

From Colonia north-west to Numnung, were the Governor had mentioned that a clay exists, then to Dugor and Colonia.

From Dugor north to the German bridge over the canal and then south-west to near the Loran Station and north to Maki and Murru.

CLAY AREAS LOCATED

There are at least two, possibly three, different types of clay deposit which exist in adequate amounts for use in small scale brick-making ,pottery, and such uses, though the actual quality of the material for such uses still remains to be proved. The indications are that they are likely to be suitable for hand making of bricks and pottery of the type made previously.

Area 1. This is the extensive area of reddish-brown soil on which the present airfield is constructed, extending from Derikan in the north, on the road to Colonia, south through Ngof to Gachlau and beyond. On Map 4 of the "Military Geology....", this area is coloured pink, and is the soil occurring above the Tomil Volcanic Formation in that area and classified as "Red Clayey Silt (MH)". It consists of a red-brown or

mottled clay, stiff, fairly plastic, free from stones, well drained and easily accessible. There is no overburden and the two sample pits dug in it found at least 0.65m of this clay and it is likely to be much thicker.

The samples were taken as follows:

No. 261179A. At close to sample point 31 of Map 4 of 'Military Geology...'. Approx 300m north of Gachlau, turn left, i.e. west, and proceed 58m down the track towards Malai. Then go 17m south on an open, uncultivated area free from jungle growth. The sample was taken at a depth of 50-60 cm.

No. 261179B. Near Derikan. The magnetic bearing to the U.S. flag flying near the airport was 142° and the range 550m. The bearing to the south end of the nearby lake was 180°, i.e. south. The bearing to the north end of the lake was 210°. The electricity post at the nearby crossroads bears 10° and the range was 110m. This hole found mottled brown and light red stiff clay, fairly plastic and uniform and extending at least to 65cm. At this point a sample was taken. The area here available for development measures at least 300m by 100m and with a depth of at least 0.65m and no overburden there is 20,000m^3 available here and much more elsewhere.

Area 2. This is a huge area, making up more than 25% of the area of Yap. It overlies the Yap green schists, extending North of Derikan and the road there and will be exposed when the new airfield is built. It extends north to Dugor and Numnung and beyond. The thickness available is variable and is as little as 30cm in places. The overburden is usually 20cm of earth and stones. Samples were taken as follows:

No. 261179C. North of the road near the airport. Bearing to the electricty post at the crossroads = 200° and range 70m. Bearing to the US flag 145° and range 450m. A uniform brown-yellow clay occurs from 20cm depth to 75cm depth and then there is green schist.

No. 271179A. Near Numnung, on the south side of the road in a cutting. A maximum of 60cm of brown-yellow clay, sl. plastic, above green schist. Overburden is 20cm of stoney earth.

Area 3. This occurs around Maki and Murru on Gagil-Tomil. The surface consists of 35cm of limonitic nodules. Beneath is a clay.

No. 271179B. After 35cm of overburden, there is more than 75cm of stiff brown clay, fairly plastic. It probably extends much deeper as the Military Geology report mentions it can be up to 27ft thick.

Conclusions. The initial conclusion is that there is much clay on Yap, especially lying above the Tomil Volcanic formation such as around the present airfield, for example, with easy accessibility and adequate thickness for small scale industrial use. A thinner deposit of clay, usually less than one metre thick, lies on top of the Yap green schists and is very extensive. A thicker clay, possibly up to 27 feet, occurs around Maki and Murru. The clay above the green schists was used for coiling pots. It is likely that bricks can be made from all three clay occurrences which have been found on Yap. Samples are being held in the office of Mr. Philip Rrig pending a decision on what testing, possibly in Australia, should be done, if any.

Neville R. Hill, M.Sc.
Construction Materials Geologist
November 1979.

APPENDIX VI

INITIAL REPORT BY NEVILLE R. HILL, UNIDO FIELD GEOLOGIST

on an

INVESTIGATION OF CLAY DEPOSITS FOR CERAMIC USE IN PALAU

December 1979

1. PURPOSE

The purpose of the mission was to determine the location, quantity and potential uses of available clay deposits, and collect samples as necessary, by means of study of already existing information and field work in selected areas. The mission would not specifically determine the market for ceramic products or make proposals for the design and establishment of manufacturing units. These were to be amongst the duties of a ceramic technologist to be recruited by UNIDO in the near future.

2. SUMMARY OF PREVIOUSLY AVAILABLE INFORMATION

The following data was collected in the form of reports available from UNIDO in Vienna, UNDP in Fiji, the Bureau of Resources in Saipan and discussion with people in Palau.

2.1. Clay Deposits. A fairly detailed description of the geology and soils of Palau, with excellent maps and test results on samples for plasticity, granulometry, etc., is given in "Military Geology of Palau Islands, Caroline Is. Intelligence Division, Office of the Engineer HQ U.S. Army Forces Far East & Eighth U.S. Army (Rear) 1956." Plates 27 and 30 of that report indicate the soils and clay types likely to be of most interest to the present investigation as follows:

Plate 27 Engineering Geology	Plate 30 Engineering Soils
Weathered from volcanic rocks:	
Unit 3 weathered volc.breccia.	- Unit 3 deep, lateritic, sandy clay & clay.
Unit 4 weathered tuff.	- Unit 5 deep, lateritic, silty clay.
Unit 6 lt.coloured mottled clay	- Unit 3, mostly.
Sedimentary rocks:	
Unit 7 Clay with lignite.	- Unit 2 shallow sandy silt over sticky plastic clay.

From a ceramic viewpoint, it is of the greatest significance that a range of clays exists, from those that are plastic to those that have a silty or even sandy element in them so that there is a good possibility of achieving the optimum desired properties in moulding, drying, and possibly also in firing, by making up mixes of two or more different clays.
From the maps, the areas where these different clays occur to the greatest extent are 1) around Ngatbang and the island of Ngerasch (Ngerassa), 2) Airai, south and west of the present airport, and 3), to a lesser extent, Oikul. (Japanese spelling= Goikul).
Samples from Ngerasch (4), Ngarsuul (1) where a pottery was operated recently, Ngatbang (1), Airai (3) and Ngerdmau (1) have previously been collected by one of the potters at Ngarsuul, in collaboration with the Palau Economic Development Office, and were sent, via the SIDFA at UNDP, Fiji, to Alfred University in New York State*. A summary of the throwing and moulding, drying/firing shrinkage and cracking tendency, etc. is given in Appendix 1.

In summary, the results suggest that the Ngerasch deposits are more suitable for making ceramic filters and structural clay products, whilst the Airai material was found to be better for sculpture and making thrown products.

* i.e. NY State College of Ceramics, Alfred, NY 14802.

In 1940 the white clay deposit at Oikul was surveyed and found up to 5 feet of white clay close to the surface in the area to the north of the stream which has been dammed to supply water to the shrimp ponds. The map of the deposit, with sections, forms Fig.12 of the "Military Geology..." report and estimates that 23, 000 metric tonnes of material are available. Peat or lignite also occurs there. (see p.268 of the report). The clay was said to be of 'fair ceramic quality'.

The deposit of clay on Ngerasch Island, in Karamado Bay is, like the Oikul and Ngatpang and Airai deposits, an occurrence of clay of the Airai Formation, and also has associated lignite seams, the thickest being up to 1 metre. The Airai clay is described in detail on pp.52-55 of "Military Geology..." and it and the lignite are also covered from their economic aspects on pp.259 to 268 together with a map of the deposits on Ngerasch Island, borehole sections and analyses of the lignite. On Ngerasch Island, the clay extended from the surface to a depth of 4 to 8 feet and from the sketch map on p.261 appears to extend over at least 180,000 square metres. Hence reserves there could amount to around 350,000 cubic metres, or say 800,000 metric tonnes.

The proportions of kaolinite and montmorillonite in the Airai clay formation vary from almost pure kaolinite (i.e. almost a china clay) in Oikul to predominantly montmorillonite, with some kaolinite (i.e. more like a ball clay)on the east side of the main road cut on the east side of Karamado Bay (see p.53 of "Military Geology.."). This is of considerable significance to the ceramist as it means that it should be possible to find rather refractory type kaolinite rich clays suitable for refractory bricks (fire bricks) and more highly plastic ball clay type clays which are very useful for raising the'mouldability' of the otherwise not so plastic white kaolinite clays.*

One of the problems of the sampling done prior to the present mission is that there is uncertainty, owing to inadequate field description of the clay and its precise location, as to which particular clay material the Alfred University ceramic tests refer.

* Similarly, any excessive drying shrinkage, and possible tendency to cracking experienced with the very plastic, fine ball clays can be modified by addition ofkaolinite rich clay and silty or sandy clays.

2.2.Previous Ceramic Activities. There appear to have been three separate phases of ceramic production in Palau. The first was that of pottery production by the Palauans some time in the distant past. According to the report of August 1977 by Sandy Vitarelli (referring to Ceramic Research & Teaching Program of Palau High School) the former pottery centres were Ngerard and Ngatpang. That original activity no longer survives.

Then, in 1939 to 1942, (see pp.267 to 268 of "Military Geology.."), Sakugawa, an Okinawan, produced for local consumption around 250,000 pieces of ceramic ware including bricks (probably also fire bricks), pressed roof tiles, pipe, braziers and pots. His kiln was on Ngerasch Island, and was fired with mangrove wood and then wood, charcoal and lignite. The clay used was that overlying the lignite on the island. The products were said to be of fairly good quality (and the many remaining pressed tiles of various designs at the kiln site appear to be good, without cracking or warping) though apparently shrinkage during firing was about 10%, which is high. The fact that there is this certain evidence that such structural clay products can be produced with clay from the Airai formation, on Ngerasch Island, with or probably without other clay additions to the mix, is important in reaching a

conclusion as to whether the available clays on Palau can support the introduction of a local brickmaking industry, for example.

The most recent phase of ceramic interest began about 7 or 8 years ago and ended in about June this year, and was in two locations: the Palau High School and the Ngarsuul Pottery at Kless. Reports have been written on the state of the Ngarsuul Pottery as at December 1977 by the Peace Corps ceramist volunteer Herbert Mayher who has now left and who took over the running of that pottery from members of the Vitarelli family and the Palauans such as Wilbert Tulop and James Ngirmechesengel* who worked there with them. (Wilbert Tulop has gone to Guam and James Ngirmechesengel attends the Palau High School).

The previously mentioned report by Sandy Vitarelli of August 1977 described the clays being used by the Palau High School pottery, which were all from Babelthuap Island, and their performance, and the glaze mixes used --- made from imported materials.

At both potteries production was hand thrown, i.e. using wheels mostly propelled by the foot, in the traditional manner.

In Appendices II and III, the present state of these two potteries including the available equipment is given following inspection by the field geologist during the present mission.

The fact that this ceramic activity no longer continues on Palau is not due to any deficiency with the raw materials or of the equipment that was used, or of the enthusiasm and dedication of those who were responsible in establishing and running the two potteries. Without knowing the full details, it seems probable that, besides the conclusion of funds to continue running them, there was some lack of interest by the local community in the operation of the potteries which did not seem to them to represent a worthwhile type of occupation.

The important finding, if a decision is taken to restart the pottery production activity on Palau, is that at Kless a complete pottery exists, with virtually all necessary equipment. Although the Palau High School pottery was vandalized some time ago, much exists there which is of potential value to anyone determined to restart the activity either in its existing location or removed elsewhere, such as to the clay deposits of the Airai formation near to the airport.

3. FIELD WORK

A total of 2½ days were spent in the field to visit the clay deposits said to occur at Ngarsuul (Kless), Oikul, Ngatbang and Ngerasch and the area of Airai clay formation lying between the airfield and the bombed Japanese building. In view of the short time and the variety of clays available from these sites, it was not possible or necessary to visit the lateritic clay at Ngerdmau or any other locations.

3.1. Ngarsuul. The precise location from which the Ngarsuul clay was dug for the pottery at Kless was indicated by James Ngirmechesengel and lies 20 metres to the north of the present pottery building.

Previous sample and results. These are conflicting. The Alfred University results on Sample No.PAL-D1 (Ngarsuul) suggest that it is alright for structural clay products rather than for thrown pottery, that it is too short and needs a plastic clay to be added to it. However, the combined drying shrinkage and firing shrinkage (D.S., F.S.) is very high for such a clay i.e. 27%. According to Vitarelli, the Ngarsuul clay is a good pottery clay, for earthenware, and should be mixed with Ngerasch or Oikul, which are less plastic clays, 50:50. The firing temperature

is relatively low compared with the other Palau clays.
Visual characteristics. A sample taken from under standing water was medium grey, highly plastic, more like a ball clay. Uniformity unknown as could not be seen in situ or free from roots and grass.
Possible use: as a pottery clay when mixed with less plastic kaolinite rich or silty clay.
Quantity available: not determinable owing to the very poor exposure - covered by tall grass and water. No other exposures visible. May be a quite small deposit.(Information from Neil Babik of the present U.S. Soil Survey team, is that a white, mottled clay is exposed in the bend of the river about ½km above the Ngarsuul pottery site and this probably belongs to the Airai formation).
Accessibility. Difficult; takes 35 minutes by fast boat from Koror at high water. No land access? Distance from Kless landing point is less than 100m. Difficult to obtain a clean clay owing to the height of the water table and much tall grass, etc. The soil overburden appeared to be about 15cm thick.
Preliminary conclusions. This is a potentially important clay in view of its high plasticity but it cannot be used without mixing with other, less plastic,material in at least equal amounts. The deposit here may be quite small. May be the 'grey, impermeable plastic clay'of unit 8 of the map of Plate 30 of "Military Geology...". The presence of this clay alone does not appear to be sufficient justification for the decision to locate a pottery at this place. There are other, more suitable,locations for a pottery in Palau to which it would be appropriate to transport the quantities of this clay that would be required if, in fact, the plasticity of other clays, such as in the Airai formation, near the airport, was not found to be adequate. Sample: none taken during present visit.

3.2. Oikul (=Goikul). The location lies about ¼km north of the few houses forming the village of Oikul. The map on p.269 of "Military Geology..." indicates that all of the 23,000 metric tonnes found by boreholes in 1940 lie to the north of the stream on which is the dam to supply water to the recently built shrimp ponds. Outcrops of white and white-mottled-with-red clay occur about the track from near the dam north and north-west for at least 400m and seems to underlie the sparsely wooded, open area having only moderate slopes. According to the aerial photograph ref. 37 4-101of the present U.S.Soil Survey, used by them in their work, the area of white Airai formation clay (with some lignite) may be more extensive than the 1940 map indicates and may extend south of the stream. It may include most of those areas recorded by that Survey as units 541,554, 540 and 514.
Previous samples and results. This deposit was not sampled along with the other Palau (and Ponape samples tested by Alfred univ.
Visual characteristics:Sample No. 301179A. White clay, some red mottling, from auger hole at 60 to 90cm depth. 35m from the dam and the bearing to the dam was 120° mag. Moderate plasticity, no sandy or stoney particles.Similar to 'white clay' near the airport.
Possible use: as a brick clay but the firing temperature may be rather high and possibly produce a firebrick. Mixed with ball clay for pottery. On its own for ceramic filters?
Quantity: In excess of the 23,000 metric tonnes measured in 1940.
Accessibility:from the B-K bridge it is 8.9 miles, i.e. about 14 km by a dirt road passable by four wheel drive vehicle. The clay occurs

at the surface or else with a very thin soil and grass or fern cover. The area is fairly well drained and there would be no problem due to ingress of water into a mined area.

Preliminary conclusions: Little is known about the properties of this clay. Vitarelli fired it to cone 7 to 8 and thinks it would go higher than that. It is probably similar to the white clay (sample no. 031279A1 and 031279B1) that occurs on the higher ground, at the road level, between the bombed building and the airport. It may be good for refractory bricks of moderate performance such as common firebricks. Probably insufficient plasticity and green strength on its own, i.e. without some ball clay, for moulding or throwing pottery items. However, the quantity available is useful and it is accessible fairly easily and may have desirable differences in its firing behaviour compared with the other 'white' clays at Ngerasch and Airai (airport).

3.3. Ngatbang. Clays of the Airai formation occur in Ngatbang municipality around the east and south sides of Karamado Bay. The locality visited during this mission was at Klubed, in Ngeruchob, in Ngatbang district. There are no houses there now. One exposure of medium grey, slightly plastic clay was shown to us by Mr. Taurengel Otobed, headmaster of the Modekngei school at Ibobang, in Karamado Bay, and father of Mr. Demei Otobed, the head of the Entomology Centre in Palau. The location lies south-east of Ngerasch Island, at a point on the mainland reached by a very narrow passage of water through the mangroves that run down the east side of the island. Approximately 95cm of clay is exposed at the side of a stream and becomes darker and more mottled towards the base. The whole area is luxuriant jungle growth and wet underfoot. This clay is said to occur just below the surface over much of the area. Sample no. 301179B was taken here.
Previous samples and results: A sample from Ngatbang ((NL)PAL A-1) was tested at Alfred University. It was fairly plastic, had a total drying and firing shrinkage of 20% and was suggested as suitable for hand moulding and as a throwing body. The Ngatbang clay used at Palau High School was white and came from the old village site, in the forest about 200yds from the village centre and is described as very good, though there is mention that it is mixed with ball clay in use. Here again, there is doubt as to what the Alfred Univ. tests refer to - was it the white clay like that used by the High School, or the grey clay seen during the present mission?. No details are given except: PAL A-1, Ngetbang, 1 foot below top soil.
Visual characteristics: a medium grey to darker clay, low plasticity, but not due to silty particles - probably mainly kaolinitic rather than montmorillonitic.
Possible uses: the clay seen in the field is probably not the same as that tested at Alfred Univ. The grey clay may be suitable for brickmaking if it is not too refractory. It would need more plastic clay added to it for pottery use.
Quantity: impossible to estimate in the field owing to brief nature of visit and no means to make an extensive borehole investigation. From the maps, there is likely to be large quantities lying in the Ngatbang municipality area. Exposures appear to be uncommon.

Accessibility: Not easy. From T Dock at Koror to this place takes about 45 minutes, of which about one third of the time is for negotiating the mangrove crowded narrow access channels.(Ngerassa Island to Koror with a 85 HP outboard boat takes just under 30 mins at high water). To remove clay would require the felling and clearing of forested land which is close to sea level and is wet. Some time in the future there will be a road built from Airai in the south of Babelthuap which will pass within about ½ mile of this location according to Mr. Demei Otobed. Once the thick jungle is removed there is only a thin soil covering above the grey clay.

Preliminary conclusions: this area has potential for development of its clay resources and has supported small scale pottery making in the past. At present it is very difficult to dig out the clay and much expense would be needed in clearing and road construction. There are other areas on Babelthuap, such as the airport location in Airai, that are more suitable and have a choice of three or more clays.

3.4. Ngerasch (=Ngerassa). This is an island in Karamodo Bay surrounded by mangrove trees. Exposures of Airai formation clay, together with a bed of lignite up to 1m thick, occur over the middle and southern part of the island. The location is reached by fast boat from Koror to a landing 'dock' on the west side of the island. White, white-mottled with red and yellowish clay is exposed on the first part of the path to the 1939 kiln and in many other places.

Previous samples and results: Sample No. PAL -B1 and B2, described by Vitarelli as 'Ngerasch yellow buff', and 'Ngerasch Red Ochre' respectively, were tested by Alfred University. They came from points along the path from the dock to the old kiln. B1 had a total shrinkage of 19%, as found to be very short and not good for throwing and its suggested use is for structural clay products which is reasonable in view of the production of bricks, tiles, etc. that was done here - though the items were pressed, rather than extruded. (The remains of both a brick press and a tile press, as well as other items, still exist on Ngerasch). The red ochre, B-2, was also found to be of low plasticity and was suggested for use as an engobe. Vitarelli used a yellow clay from near the old 'pottery' site -presumably the brick and tile works - and found it to be possible to use it alone, even though it was 'non-plastic' (!) though it was also mixed with ball clay. Alone it fired white in oxidation, red in reduction.

The quality of the products made at Ngerasch, appeared to be quite acceptable, judging by the items that still remain there. In pressing, there was no difficulty in pressing the tile shapes without lines of cracks occurring along the fold of the tile.

Visual characteristics: it is a white, or mottled or yellowish clay of relatively low plasticity but adequate for pressed products but not for extruded items.

Accessibility: once on the island, the clay is easily accessible there being little or no overburden and only short soil and grass as seems to be common with this clay unit. There is no problem due to drainage, the island being sufficiently elevated above

sea level.

Preliminary conclusions: The principal advantage of this location is that there is proof that structural clay products of acceptable quality can be made with the clay here. Adequate reserves exist, both on Ngerasch and the neighbouring mainland around Ngatbang municipality, for production to be restarted if the demand should arise. The near vicinity of the landing place and access to the open sea would make distribution of the products by boat relatively easy. However, it is likely that the white clays of Airai are also suitable for structural clay products and are better located as well as being in large amounts.

3.5. Airai. This location is one of others ,such as Oikul, that occurs in Airai District. Airai 'proper', here refers to the location lying to the south of the present airport and north and west of the bombed Japanese building. Samples taken during this present mission come from two nearby points. Samples nos. 031279A1, A2, and A3 come from an erosion scar lying on east sloping ground, a distance of 330m from the airport windsock which bears 345° mag. from the location. (The gable of the bombed building bears 180° mag and is distant 160m from the location.) It is marked by three short lines (= erosion scar) on photo ref. 36 4-85 of the present U.S. Soil Survey.

The other sample location lies just to the north of the road approaching the airport building. The distance to the windsock is approx. 110m and the bearing to it from the location is 60° mag. This is the east end of a gulley from which white or white-red mottled clay appears to have been dug recently. The sample location for that was 031279B1.

Previous samples and results. Three samples from Airai, PAL F1, F2 and F3, were sent to Alfred University. Unfortunately, both the sketch map and the sample descriptions (F1 yellow, 1' below top soil; F2 yellow top soil and F3 grey-clay-top soil) referring to those samples are inadequate for determining the point where these clays were taken or which are referred to.(During the present mission it was found that there are at least three different and potentially useful clays in this area. All are exposed in the erosion scar.). Alfred University reported that all three samples were suitable throwing bodies, i.e. had good plasticity and strength; in fact F2 was said to be 'too plastic'and 'like a ball clay.' Vitarelli used a grey Airai clay at the High School, from 'behind old bombed building(near airport)' but one is not sure which side of the building is referred to. She describes it as a'ball clay, tight, and will not slake when dried at room temperature, contains lime'. However, all the chemical analyses by Alfred University for these Airai clays have less than 0.14% of CaO which suggests they do not contain enough lime to cause any influence on the using of these clays.

Visual characteristics. The samples 031279A1 and B1 are of white or white-red mottled clay lying at the top of the erosion scar and in the exposure close to the airport building as well as generally at the level of the road. It has medium plasticity and probably can be used for hand moulding of bricks e.g. by throwing into a sanded mould. Visually it appears similar to the white or mottled clay at Oikul and Ngerasch. Below it, near the top of the erosion scar and elsewhere, and immediately beneath the main lignite band (70-80cm thick here) is the grey clay of sample no. 031279A2. It is pale grey, uniform, plastic, 'tight',

free of silt and contains some carbonaceous matter.

The third clay sampled during the mission's visit to this location is sample ref. 031279A3 and occurs in the central area of the erosion scar as well as in the lowest area above the stream. In colour it weathers pale green but about 10cm below the surface it is medium grey and shows relics of volcanic breccia now completely weathered near the surface.(In the Palau Museum there is a sample of core of the original hard, non-weathered volcanic breccia). This green weathering clay feels that it has more coarser material present and is therefore less plastic than the other two clays both of which appear to be of sedimentary origin.

This suite of clays is potentially of much interest and importance as they have different characteristics and occur in close proximity to each other with good accessibility. It is conceivable that they could support a whole range of ceramic production, with only minor additions of other clays such as from Ngarsuul ,having to be brought in.

Quantity: Assuming the whole of the area, apart from 150' needed for the new runway additions, etc, from the Airfield to the bombed building is available, substantial reserves of these clays exist here, as well as to the west of the airport road, (and west of the bombed building.) The top bed i.e. white clay, is at least 2m thick, the grey clay is 1½m thick and the green weathering clay occurs in two horizons, each 1 to 1½m thick.

Accessibility. Both by road and to the clays themselves, accessibility is excellent. As with other areas where the white clay has been found, and possible cultivation by the Japanese, the top soil has largely disappeared. Short grass, ferns and a few pandanus trees are growing here. The distance by road from the B-K bridge is 3.7 miles, i.e. 6km.

Preliminary conclusions. It is suggested that if it is wished to promote the development of ceramic industries in Palau, then the Airai (airport) location would, so far as present development plans are known, be a suitable location with regard to availability of clay raw materials for both structural clay products and pottery.

4. FUEL.

In the firing of the kilns in the potteries at Ngarsuul (Kles.) and the Palau High School, the fuel used was oil - presumably diesel fuel.

However, in future, oil is going to become increasingly scarce and expensive and there seems no reason, at present, why local timber, which is abundant, as mangrove and other species, should not be cut and used. There is no over-explcitation of the timber on Palau at present . If necessary, fast growing species such as the Giant Ipil-Ipil, successfully introduced recently to the Philippines, might be planted to replace the cut forest. In addition, in Oikul, Airai and Ngerasch there are beds of lignite, up to 1m thick. When dried this can be added to supplement the use of wood.

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4th December 1979

STATE OF THE NGARSUUL POTTERY, KLESS, ON 29th NOVEMBER 1979

EQUIPMENT

See the list quoted by Herbert Mayher as at December 1977.

1 Lister diesel generator, HP 10, No.1169SR221, for 115v ,1800rpm, 6 KVA. Has clocked 4781 hours. Appear to be in working order when fuel is available.
1 'Shrimp' electric potters wheel.
1 'Lockerle' kickwheel.
3 locally built kick wheels.
1 Alpine low capacity pug mill.
1 Ball mill rollers, with 2 gal and 1 gal. porcelain jars.
1 55gal large capacity clay mixing machine.
1 55gal clay slip mixer.
1 only, Chause triple beam weighing scales, new to weigh to 2.61 kg. (the other similar scales could not be found).
1 75 cu.ft down draft Catenary Arch kiln - complete.
1 30 cu.ft down draft Sprung Arch kiln, not fully completed.
1 Japanese oil burner (diesel) - kept in the locked up shed.

Numerous items, including tools in the lock up shed, work benches and clay storage receptacles, etc. Pottery shed in good order. Last known time when it was in use was June 1979.

STATE OF THE PALAU HIGH SCHOOL POTTERY AS AT 1st December 1979

Is located in the area of the High School, opposite the Burger Hut Restaurant.

5 locally made kick wheels , all still in working order.
1 'pointed arch'kiln, made with Clipper D.P. 2 Split refractory bricks; partially destroyed.
1 kiln, internally 5½ ft high, 3½ ft wide by 3 ft front to back. with angle iron bound vertical edges. Is largely complete.
1 Washing up sink, uprooted from former position.
1 electrical socket board with all distributing cables torn out.

Various cupboards, sets of shelves and work benches in general disarray. The structure of the pottery is local timber frame with corrugated galvanized iron sheets. The roof is starting to leak. Said to have been vandalized about one year ago.

APPENDIX VII

INITIAL REPORT ON AN INVESTIGATION OF THE CLAY DEPOSITS OF MOEN AND DUBLON, TRUK ISLANDS, FOR CERAMIC USES

by

NEVILLE R. HILL

UNIDO FIELD GEOLOGIST

6th-11th Dec. 1979

1. PURPOSE

Together with visits to Yap and Palau, the aim of this mission was to determine the location, quantity, consistency and probable potential uses of the available clay deposits by means of study of previously available data, if any, and field work in selected areas. In addition, selected samples would be taken and proposals made, after consultation with the Government authorities, for any laboratory testing to be done, if considered appropriate.

The mission would not determine the the potential market for ceramic products, such as pottery, bricks, etc., or make recommendations for the capacity, design and establishment of of any manufacturing units. These were to be amongst the duties of a specialist ceramic technologist who was to be recruited by UNIDO at a future date.

2. SUMMARY OF PREVIOUS INFORMATION

2.1. Clay Deposits

Detailed work on the surface rocks of Truk was carried out in 1954-55 by the Intelligence Division, Office of the Engineer, H.Q. U.S. Army Pacific, in collaboration with U.S. Geological Survey personnel. The work on the soils was done by James E.Paseur and his maps of Moen and the northern part of Dublon, for instance, are included as Plates 13 and 14, Soils, of the " Military Geology of Truk " copies of which are held in the Bureau of Resources of the TTPI Government in Saipan. Besides the various soils units listed on the maps, there are detailed descriptions in the text, e.g. from p.91 onwards.

There are two main clay units in the Truk Islands:-

The Truk Clay (Unit 1 of Maps 13 & 14 of "Military Geology of Truk") covers 23% of the volcanic uplands and is a residual clay developed on volcanic bedrock, talus or colluvial boulders and the upper 10 feet are usually free from boulders. It is reddish-brown, granular and slightly plastic. On less than 25% slopes, the depth of this Unit can be 10 to 50 feet,(i.e. of adequate thickness to supply raw material for smaller scale ceramic industries. However, there may be inadequate plasticity for other than brickmaking by simple hand moulding.)

The Truk Stony Clay (Unit 2 of Maps 13 & 14) is the most common soil, at least on Moen and Dublon, covering more than 50% of the surface. It is mostly reddish-brown to yellowish-brown clay, slightly plastic to plastic, granular and with 15 to 20% or more of boulders present. Its thickness is very variable being from as little as 1 foot to as much as 30 feet. (Although often rather thin in thickness, this unit could be important for ceramic uses if the plasticity of the Truk Clay formation is found to be too little for pottery and other uses where 'mouldability' is essential).

The Fefan and other soil units are not of the type that might be suitable for ceramic purposes.

2.2. Ceramic Activities

There is no known record or mention of any previous ceramic activity, such as pot making, in the Truk Islands, that was learned of by the UNIDO field geologist apart from mention by Mr. Nauro Ete, in the Distad offices, that pots may have been found on the island of Fefan.

3. FIELD WORK

On the first day the west and south-west part of Moen was surveyed in company with Mr. Simion Leon of the Land Management Office. (In 1954-55, Mr. Leon had assisted U.S. soils geologist James E.Paseur in the soil survey of the Truk Islands for the report "Military Geology of Truk".). Over the weekend, the UNIDO field geologist traversed on foot the remainder of Moen, starting from Iras via Truk High School to Tunuk, Penia, Nemwan, Ör, Sopuk, Nemwan and then continuing again from Penia up to Peniesene and the radio mast and back down to Truk High School and Iras. A visit was made also to the site of the asphalt and aggregate operation near Unun en Nukanap.
It was planned to spend the final full day visiting Dublon. Unfortunately, all available boats were in use in connection with surveys on the other islands to examine damage caused by the recent tropical storm 'Abbe'.There was the possibility of trying to hire a boat privately but, in view of the fact that soils Map 14 indicates that no clays other than Truk Clay and Truk Stony Clay occur on Dublon, the additional expense was not warranted and the time was spent preparing this initial report and dealing with correspondence.

3.1. Epinup - a location having Truk Clay.

Location:in a cutting at the north side of the road, opposite the house of Mr. Ermut Manaka, in the village of Epinup.It is ¼ mile west of a Japanese water tank that is on the south side of the road. (Just over ½ mile east of the sampled location, the road is no longer passable by vehicles.) The Grid ref. on Map 14 = 745217.
Sample No: 071279A - at least 10kg.(retained in the Land Management)
Description: nearly 2m exposed of yellow-brown clay, slightly plastic, free from stones, beneath approx 20cm of dark grey earth bearing fern-like plants, coconut, etc. but otherwise not cultivated. Truk Clay occurs approx 50m east of the sample point at a slight crest of the road, opposite a disused cafe,and underlays a level area. Here the colour is reddish-brown. At another well exposed section on the north side of the road 0.3 mile south west of the sample point, at a point between two streams, there is 10cm of dark grey top soil and 90cm of red-brown clayey soil, slightly plastic. This Truk Clay continues northwards up the slope for about 30m or more where there are trenches dug in World War II.
Reserves: there was not the time nor the means to carry out a boring programme. However, in this area south west of Epinup there appears to be around 1m thickness of Truk Clay extending for more than 500m along the road. There are some houses but sufficient area for supplying small scale ceramic production. A larger accessible area of Truk Clay exists along the very muddy road east of Truk High School, e.g. at Levi, on the road to Tunuk.
Potential Uses: In view of its rather low plasticity, i.e. ability to be moulded and retain its shape in the moist state, from visual examination and feel, it is probable that the Truk Clay is suitable only for simple hand moulding of bricks, rather than by an extrusion

process, and unlikely to be any good for pottery use. There appear to be no other clays of sufficient plasticity with which this Truk Clay can be blended, though the Truk Stony Clay seems to have a slightly higher degree of plasticity.

3.2. Sabou - a location having Truk Stony Clay

Location: Approximately 0.4 mile, i.e. about 650 metres, south of the protestant Logan Memorial Church, and 1.85 mile, say 3 km, south of the Public Works office. The exposure sampled is at the bottom of the garden of the house of Mr. Frank Nifon, brother-in-law of Mr. Simion Leo.(Although this precise location would not be acceptable for locating a quarry or pit for digging the clay it is a relatively good exposure of the rather thin Truk Stony Clay and probably representative of the unit).
Sample No:071279B - at least 10kg , retained in the Land Management office.
Description:Red and brown clay, fairly plastic, with some roots, and some small stones and becoming less weathered volcanic rock near the base. About 50cm exposed beneath a covering of 30cm of top soil with grass.
Reserves: none available here owing to proximity of dwellings. Although tending to be rather thin usually, the Truk Stony Clay is reported as reaching up to 30 feet thickness and covers over half of the island of Moen and much of Dublon. Amounts available would be much in excess of that required for small ceramic production. Clearance of trees and other vegetation and 30cm or more of top soil would be necessary. Amongst other locations that might be possible for digging the clay is just north of the radio mast above Peniesene where there is very dark grey or black soil, granular in texture and though the ground here was dry, according to Map 14 this dark grey clay can be plastic and be 4feet in thickness down to the bedrock.
Potential Uses: If any stones are removed, it is possible that the Truk Stony Clay may be found suitable for simple pottery production as well as some simple structural clay products. Routine testing for plasticity, drying shrinkage and firing behaviour are required on both this and the Truk Clay before a more certain opinion can be reached.

4. GENERAL CONCLUSIONS

There appear to be no clays of the degree of plasticity necessary if a successful ceramic industry, covering pottery as well as structural clay products, is to be established. There are only two principle clay units occurring on Moen and Dublon, both of which have rather low plasticity and suitable, if at all, for hand moulding of bricks rather than more intricate products.

In the event that it is considered desirable to carry out any ceramic testing of the samples collected and the results prove to be industrially significant, both the Truk Clay and the Truk Stony Clay occur widespread and in thicknesses sufficient for their utilization to be practicable.

The location of these clays may be readily determined by reference to Maps 13 & 14 of 'Military Geology of Truk'.

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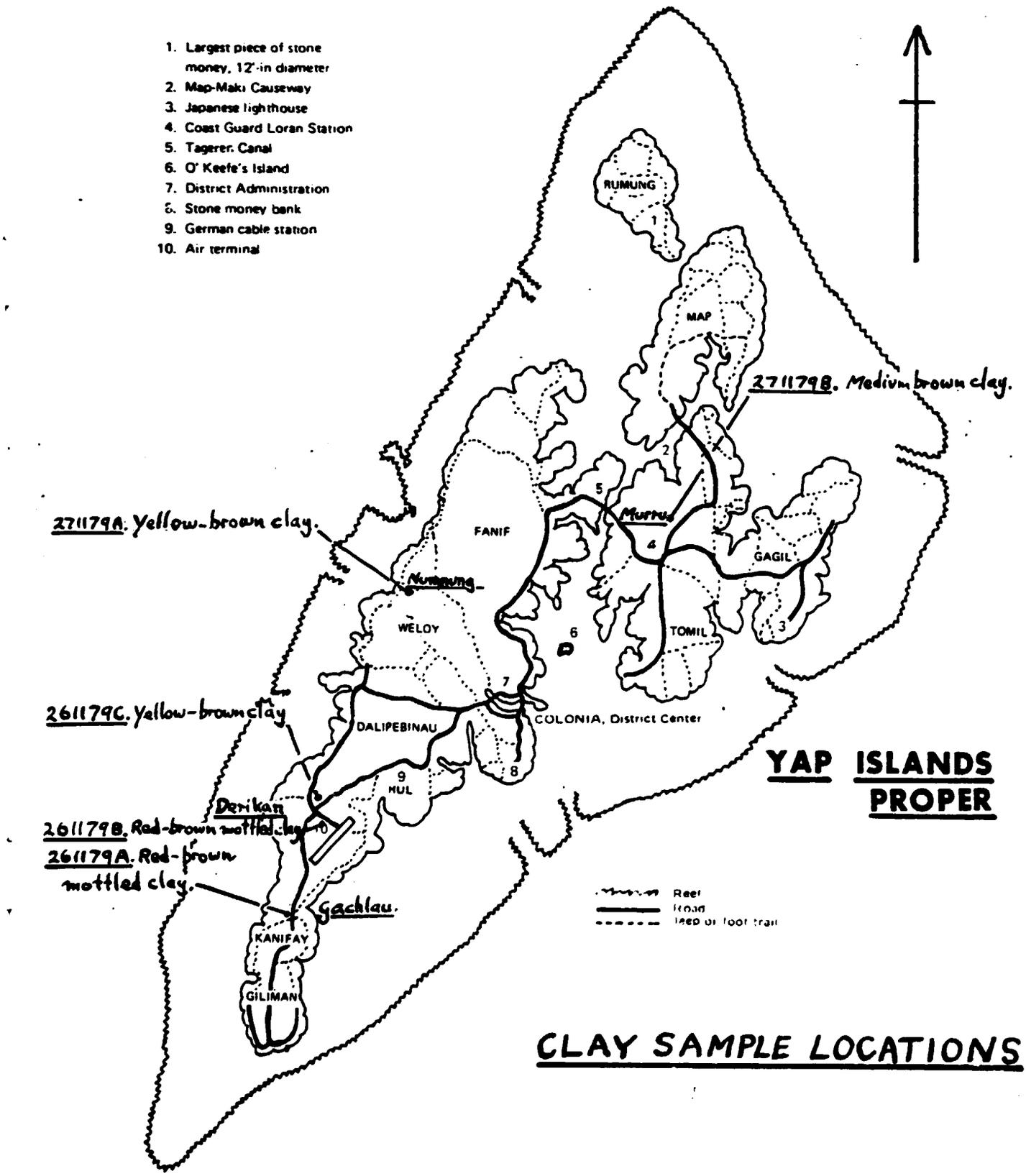
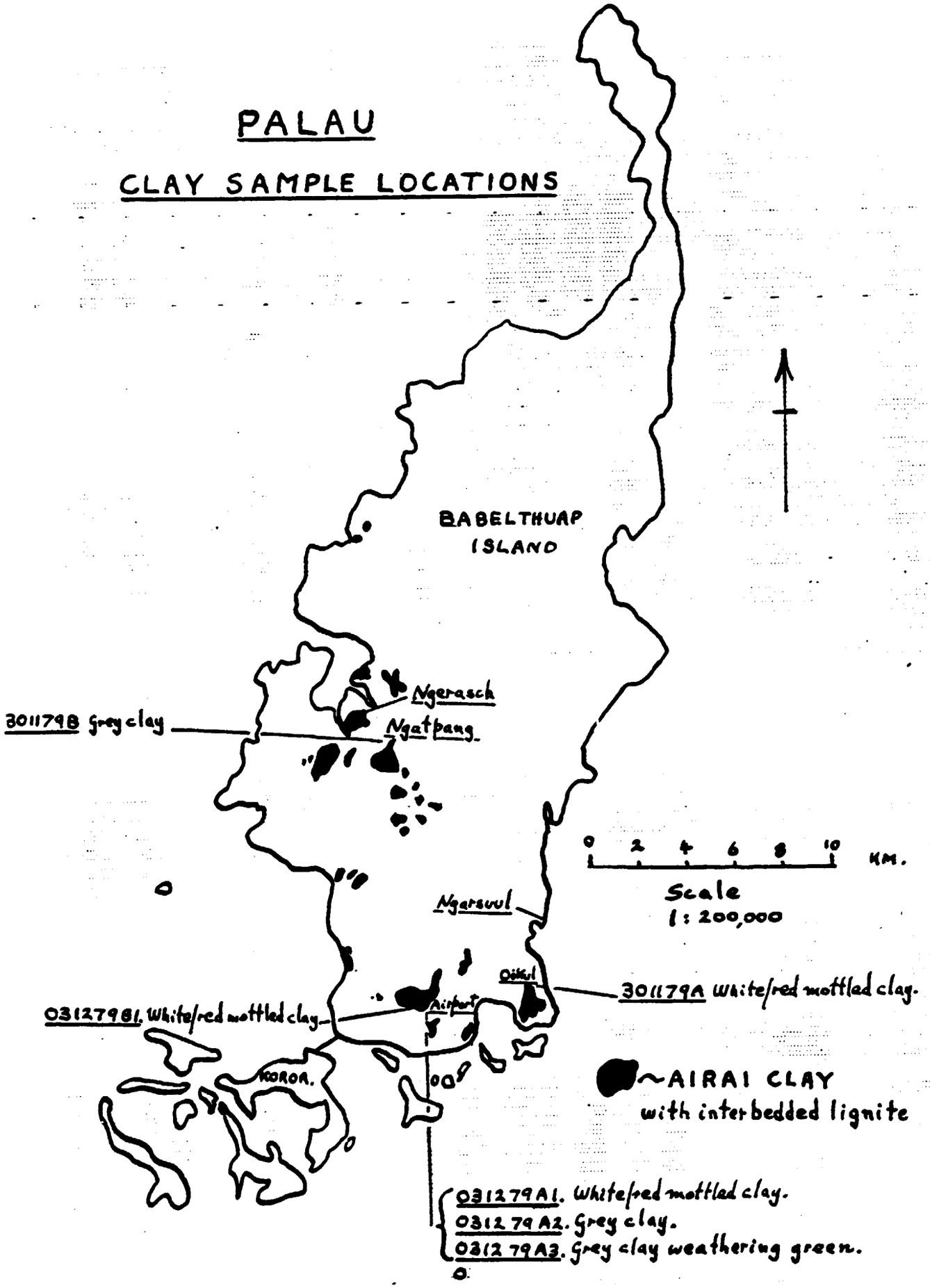
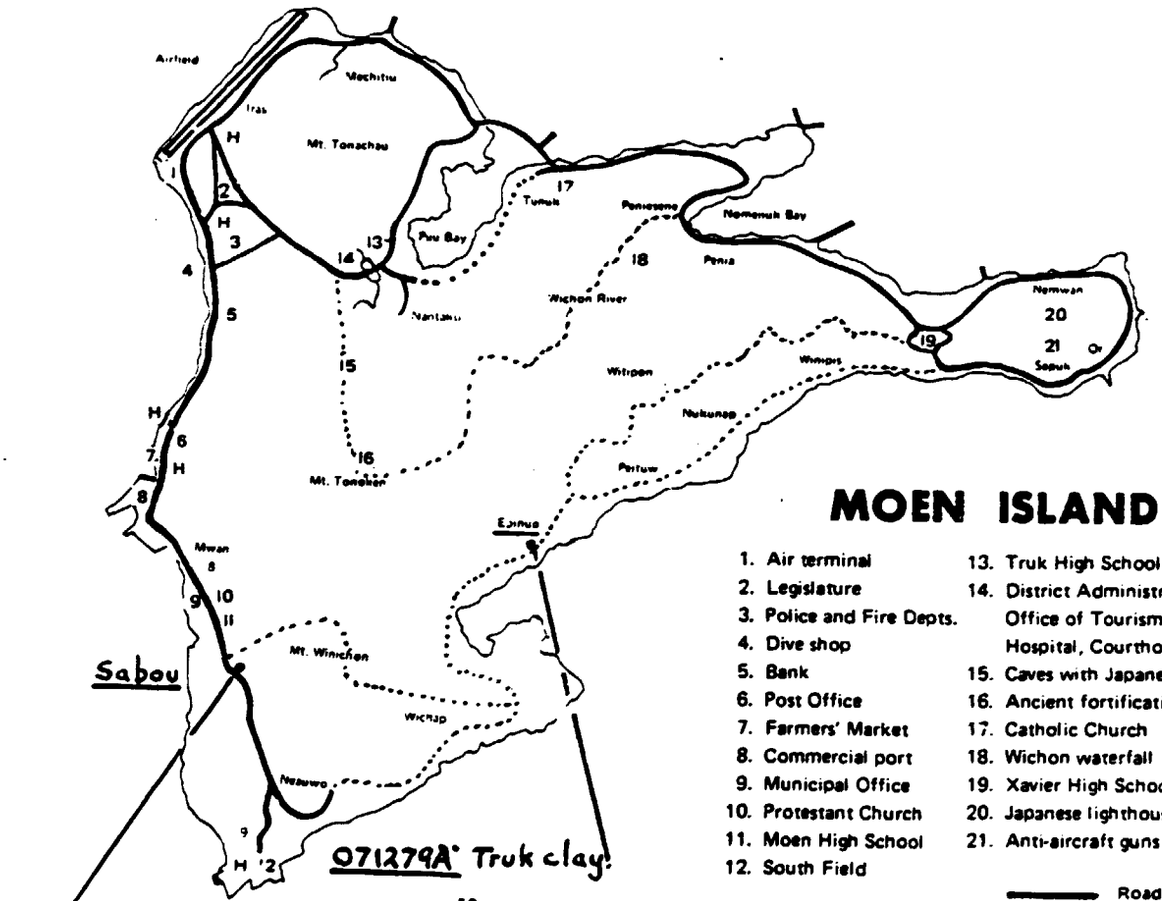

1. Largest piece of stone money, 12'-in diameter
2. Map-Maki Causeway
3. Japanese lighthouse
4. Coast Guard Loran Station
5. Tagerer. Canal
6. O' Keefe's Island
7. District Administration
8. Stone money bank
9. German cable station
10. Air terminal
RUMUNG
MAP
2711798. Medium brown clay.
2711794. Yellow-brown clay.
FANIF
Murrus
GAGIL
Numaung
WELOY
TOMIL
2611796. Yellow-brown clay
DALIPEBINAU
COLONIA, District Center
HUL
Derikan
2611798. Red-brown mottled clay
261179A. Red-brown mottled clay.
Gachlau
KANIFAY
GILIMAN
YAP ISLANDS PROPER
Reef
Road
Jeep or foot trail
CLAY SAMPLE LOCATIONS


PALAU
CLAY SAMPLE LOCATIONS
BABELTHUAP ISLAND
Ngerasch
3011798 Grey clay
Ngatpang
Ngaruul
Oikul
3011794 White/red mottled clay.
Airport
03127981. White/red mottled clay
KOROR.
0 2 4 6 8 10 KM.
Scale 1:200,000
~AIRAI CLAY with interbedded lignite
031279A1. White/red mottled clay.
0312 79 A2. Grey clay.
0312 79A3. Grey clay weathering green.

TRUK

CLAY SAMPLE LOCATIONS



MOEN ISLAND

1. Air terminal
2. Legislature
3. Police and Fire Depts.
4. Dive shop
5. Bank
6. Post Office
7. Farmers' Market
8. Commercial port
9. Municipal Office
10. Protestant Church
11. Moen High School
12. South Field
13. Truk High School
14. District Administrator, Office of Tourism, Hospital, Courthouse
15. Caves with Japanese guns
16. Ancient fortifications
17. Catholic Church
18. Wichon waterfall
19. Xavier High School
20. Japanese lighthouse
21. Anti-aircraft guns

Road
Trail
H Hotel